Corrected up to November 1872.

A TEXT-BOOK

OF THE

CONSTRUCTION AND MANUFACTURE OF THE RIFLED ORDNANCE IN THE BRITISH SERVICE.

BY

CAPTAIN FRANC. S. STONEY, ROYAL ARTILLERY,
LATE ASSISTANT-SUPERINTENDENT ROYAL GUN FACTORIES,

AND

CAPTAIN CHARLES JONES, ROYAL ARTILLERY,
CAPTAIN-INSTRUCTOR ROYAL GUN FACTORIES.

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LITHOGRAPHED PLATES

AT END OF VOLUME.

WOODCUTS.

(These accompany the respective descriptions of Stores, &c., &c., and can thus be readily ascertained by the Index.)

EXPLANATION OF ABBREVIATIONS USED IN THIS WORK.

R.M.L.	For Rifled Muzzle-Loading.
R.B.L.	„ Rifled Breech-Loading.
M.L.	„ Muzzle-loading.
B.L.	„ Breech-Loading.
S.B.	„ Smooth-bore.
W.D.	„ War Department.
W.O.	„ War Office.
D. of A. and S.	„ Director of Artillery and Stores.
L.S.	„ Land Service.
S.S.	„ Sea Service.
R.L.G.	„ Rifle Large Grain (powder).
P.	„ Pebble (powder).
R.G.F.	„ Royal Gun Factories.
O.S.C.	„ Ordnance Select Committee.
E.O.C.	„ Elswick Ordnance Company.
Expl.	„ Experimental.

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Necessity for rifled ordnance.

THE general adoption of rifled small arms necessitated the introduction of rifled ordnance, in order that Artillery might still retain its superiority over Infantry, and remain as before, the principal arm in the field, which certainly would not be the case if an enemy's skirmishers had the power of placing a battery *hors de combat* before its too short-ranged guns could be brought into action on the advancing columns.†

To supply this great want in warfare, involved a complete reformation in the architecture of Artillery, which had been almost at a standstill since the time of the Tudors, for although modifications had

* The greater portion of this chapter was originally published by Captain Stoney, in the Royal Artillery Institution Proceedings in papers entitled "A brief Historical "Sketch of our Rifled Ordnance, from 1858 to 1868"; and "The Construction of "our Heavy Guns."

† At an experiment which took place at Hythe in 1857, 30 infantry soldiers armed with Enfield rifles, picked off in three minutes the men and horses of a dummy gun detachment 800 yards distant.

been occasionally made in the manufacture of ordnance the general principles of construction remained unaltered. Any one who examines the old guns in the Tower of London, or in the Museum of Artillery at Woolwich, may see that they are of the same genus as modern smooth-bores, and even notice some specimens quite as soundly and as artistically cast as any of those of the present century, nay more, he may infer that our modern cast guns can scarcely be superior to their prototypes in range-power, or susceptibility to rifling.

Why rifled guns were not produced before.

It is, however, worthy of note, that this stagnation in the construction of ordnance was not to be attributed to ignorance of the theories of gunnery, but to the backward state of metallurgy and mechanism, for professional as well as amateur artillerists have even at remote periods understood the value of rifled guns, but their endeavours to obtain them were rendered abortive by the want of suitable materials and proper machinery.*

Principal inventions with rifled pieces from 1615 to 1851.

* The following is a list of the principal home and foreign inventors and inventions up to 1858.

We have selected almost all the names of the English inventors out of nearly 200 whose proposals are described in "MS. notes on the various designs for elongated "projectiles for smooth-bore and rifled guns, which have been from time to time con-"sidered by the Ordnance Select Committee down to 1858," compiled from the records of the Committee by Lieut.-Colonel (now Major-General) A. G. Burrows, Royal Artillery.

For the foreign inventors we are indebted principally to an able paper by Captain R. A. Scott, R.N., published in 21st number of Vol. VI. "Journal of the Royal United Service Institution":—

In the Arsenal of St. Petersburg is a gun $2\frac{3}{4}$ inches in diameter and 62 inches in length of bore, which was rifled in nine grooves in 1615.

In 1661, the Prussians experimented at Berlin with a gun rifled with 13 shallow grooves.

In 1696, the elliptical bore was known and had been tried in various parts of Germany.

In 1745, the date at which Robins was experimenting in England, the Swiss already possessed small rifled pieces.

1746. Munich had a rifled breech-loader made, and T. Senner was engaged in rifling various guns.

1774. Experiments with elongated projectiles fired from a 6-pr. S.B. gun were carried on at Woolwich by the "Military Society." (This Committee existed previous to the formation of the "Board of Officers" which was succeeded by the Ordnance Select Committee.)

1776. Dr. Pollok proposed elongated shot for smooth-bore pieces.

1790. Mr. Wiggin made designs of a rifled gun and belted projectiles.

1803–1806. Proposals by Messrs. Davies, Barlow, Spencer, Eckhart, &c. were considered by the Board of Officers.

1816–1819. M. Ponchara, a distinguished French Artillery officer, was making various experiments with an old gun which he had rifled with 13 grooves.

1820. Captain Cullen, R.M. Artillery, proposed cylindrical shells filled with bullets without any bursting charge.

1821. Lieut. Croly, h.p. 81st Regiment, proposed *B.L. cannon and lead-coated projectiles.*

1823–32. *Lieut. Norton* proposed explosive shells, and a rifled gun.

1826. Experiments were with some cylindro-conical percussion shells, designed by Lieut.-Colonel Miller, of the Rifle Brigade.

1833. M. Montigny of Brussels invented a breech-loading rifled piece.

1842. *Colonel Treuille de Beaulieu* first presented to the French Government his plan for rifling M.L. guns, with a few large grooves for studded projectiles, which was afterwards adopted in a modified form, and is now known as the French system.

1845. *Major Cavalli*, a Sardinian officer, invented a breech-loader (submitted to Ordnance Select Committee, 1850), rifled with *two* grooves for a ribbed shot; his guns were used at the Siege of Gaeta in 1860.

1846. The Swedish *Baron Wahrendorf* proposed the system of using lead-coated projectiles with shallow-grooved breech-loaders. He also tried the Cavalli projectile, and rifling with guns closed at the breech on his own plan, whilst Lieut. Engstroem of the Swedish Navy affixed hard wood bearings or buttons to an iron projectile.

Such then being the state of the case it was indeed fortunate for the ascendancy of Artillery that, owing to the progress of civil engineering, the requisite improvement in metallurgy and in mechanical appliances should have opportunely taken place in recent years. It is only of late that the manufacture of cast-steel as a material for rifled ordnance has made rapid progress, whilst the difficulties which used to attend the forging of wrought-iron in large masses were so great, that a heavy anchor was one of the greatest achievements of the forge-master until the comparatively recent introduction of steam hammers enabled him to forge our modern monster guns; and, thanks to the able mechanicians of the day, we now have rifling machines so perfect and easily manipulated that the operator could if he pleased engrave his name in the bore of a gun, and withal so accurate is their action that they work "true" to less than $\frac{1}{1000}$th of an inch, a dimension which can now be very easily measured by means of a Whitworth's micrometer, though fifty times too minute to be ascertained by the primitive measuring instruments of the last generation of mechanics.

Lancaster guns used in 1854.

There may be still a good deal to learn about the construction of ordnance, but our knowledge of it has greatly increased since first the necessity for rifled guns arose. The tendency then was to utilise the stock in hand, *faute de mieux*, and when hostilities broke out with Russia in 1854, some 8-inch and 68-pr. cast-iron guns were oval bored on Mr. Lancaster's plan and sent, by way of experiment, to the siege of Sebastopol, but they turned out a failure, as in most cases the straight sided projectile then used jammed in the spiral bore and ruptured the chase.

Steps taken by the continental powers.

In the lull which succeeded the Crimean campaign, Napoleon III. turned his attention to the rifled artillery problem, and came to the conclusion that the readiest mode of solving it would be to rifle his bronze field guns on Colonel Treuille de Beaulieu's plan, and at the battles of Magenta and Solferino, in 1859, some of these rifled field batteries were used by the French with great effect.

Wahrendorf's and Engstroem's designs were submitted to the Ordnance Select Committee in 1855.

1852. H.R.H. Prince Albert proposed a concussion shell, Lord Clarence Paget a rifled projectile, Lieut.-Colonel Stevens, R.M. Artillery, a plan for rifling 13-inch sea service mortars; Mr. Mallet an improved form for rifling cannon shot and shell.

In 1853 proposals were submitted to the Ordnance Select Committee by Lieut.-Colonel Grant, Captain Norton, Captain Jodrell Leigh, Signor Verga, &c., &c., &c.

In 1854, by Major Parlby, *Mr. Lancaster*, Admiral Duff, Quartermaster-Serjeant Macbay, R.A., Major Parsons, Major the Hon. W. Fitzmaurice, Major Vandeleur, R.A., Lord W. Fitzroy, Mr. G. Nasmyth, Captain Anson, R.A., *Mr. Haddan*, Mr. (now Sir W.) Armstrong, Mr. Alfred Jeffery, &c., &c., &c.

1855. *Captain Blakeley*, R.A., patented his method of forming guns of an internal tube with cast-iron or steel rings heated and shrunk over it, and Sir J. Woodford, Captain Fowke, R.E., Messrs. Goddard, *B. Britten*, Underwood, Skelton, &c., and the Revs. J. Bramball and R. Potter, brought forward various designs.

1856. General Timmerhans of the Belgian Artillery invented a wad which by taking the rifle grooves gave rotation to the elongated shot.

1857. Mr. (now Sir Joseph) Whitworth submitted his system of ordnance.

In short, it appears from the records of the Ordnance Select Committee that up to 1855 experiments had been made with rifled guns and projectiles for half a century in this country, but without any satisfactory result. The projectiles tried were very numerous, most of them were intended to be fired from S.B. pieces, the necessary rotation being obtained either by the action of the gas in the gun, or of the air, on the peculiar shape of the shot.

The remainder were generally fired from special cast-iron 9-prs. rifled with four grooves, making a quarter turn in the bore. Specimens of those experimental projectiles are preserved in the Royal Arsenal; officers desirous of "inventing" a *new* shot or shell are recommended to examine previously this heterogeneous collection.

Early in 1860 the Austrians made definite trials between B.L. guns with lead-coated projectiles and M.L. guns rifled for studded shot on the French plan, and decided in favour of the latter system as being simpler, and, considering its application to the existing stock of their bronze and cast-iron (when hooped) guns, generally more expedient; the Italians and Swedes, who at first tried breech-loaders, followed their example, as did also the Spaniards and Dutch, whilst the Russians, Prussians, and Belgians adopted breech-loaders of cast-steel, manufactured by Herr Krupp, of Essen.*

The Armstrong B.L. system.

Meanwhile our own authorities carried on careful and extensive experiments with wrought-iron rifled B.L. guns, constructed by Mr. (now Sir W.) Armstrong, whose system was brought to official notice in December 1854, when a few guns were ordered for trial.

"The first of these, a 3-pr., was delivered in July 1855, and reported on favourably by the Ordnance Select Committee, who desired to make further experiments.†

"The gun was re-bored up to a 5-pr., and in December 1856 was tried near Newcastle in presence of Colonel Eardley-Wilmot, R.A., Superintendent Royal Gun Factories, who reported that at 1,500 yards and 2,000 yards the gun had made remarkably good practice."

A second gun, an 18-pr., of the same weight as the 9-pr. bronze field gun, was experimented with at Shoeburyness. This gun showed great strength, precision, and range power, and subsequent experiments with larger guns only confirmed the excellence of the system.

"At the same time extensive experiments were carried on to test "whether any safe method of strengthening cast-iron guns could be "found, or whether any better, speedier, or cheaper system of construct- "ing rifled ordnance existed than that proposed by Sir Wm. Armstrong. "None such having been found within the period for inquiry, the Arm- "strong system was completely adopted;" and in order to obtain a supply of the guns and projectiles as soon as possible, so that we might not be behind other nations, Government not only entered into a contract in January 1859,‡ with the newly-established Elswick Ordnance Company, but commenced their manufacture in the Royal Arsenal, Woolwich.

In February 1859 Sir Wm. Armstrong was appointed engineer of rifled ordnance, and in the following November he became also Superintendent Royal Gun Factories.

Our field artillery was soon furnished with the new guns, and a goodly number, especially of the larger natures, were, at the urgent

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* For a detailed list, however, of the ordnance of foreign powers, giving the material, dimensions, and systems of the several guns employed, the reader is referred to General Lefroy's "Hand-book for Field Service, 1866," pp. 329–36.

"It is to be remarked generally that no account is taken in this table of those powerful rifled guns manufactured in this country (principally by Sir Wm. Armstrong & Co., Elswick, Newcastle), which are known to have been purchased by the Governments of Turkey, Egypt, Italy, Denmark, the South American Republics, and even Japan."

† This and a few of the succeeding paragraphs are abridged from the Blue Book, containing the Report of the Select Committee on Ordnance Expenditure, which were appointed by Government in 1862, and submitted their Report 23rd July 1863. The members of this committee were:—

Mr. Monsell.	Sir Frederick Smith.	Major O'Reilly.
Sir George Lewis.	Mr. Dodson.	Mr. Beecroft.
General Peel.	Sir John Hay.	Sir Morton Peto.
Captain Jervis.	Lord Robert Cecil.	Mr. Vivian.
Mr. T. G. Baring.	Mr. Laird.	

‡ This agreement terminated in 1863, since which time all the new Government guns have been made in the Royal Gun Factories.

request of the Admiralty, supplied to the fleet, and subsequently the whole series of Armstrong guns, as given in the table (page 77), was added to our armaments.

Their superior range and accuracy.

The increase in range and accuracy obtained by the adoption of these rifled guns was no doubt very considerable. It has been proved by experiments that whilst the 12-pr. B.L. gun could put one shot out of every two fired into a rectangular space 22 yards long (*i.e.*, in the direction of the range), by 1·3 yard wide, at the distance of a mile, the 18-pr. S.B. gun could, under similar conditions, only hit a space 121·7 yards long by 25·8 yards wide, and, in short, that the rifled gun could make better practice at a distance of two miles than the smooth-bore could at one.

Their defects.

On the other hand, the B.L. system wanted the simplicity of the smooth-bore, and required a great many implements for its repair. Moreover, as has been proved by the experience of ten years, serious accidents were likely to take place from various causes, such as the breech-screw being improperly screwed up, the vent-piece being weak or ill fitting, &c.; * and it is therefore probable that if we had been in the meantime engaged in a war, in which the B.L. guns had to be used in large numbers, such accidents would have considerably impaired their success; as it was, however, they have been only used on a small scale before an enemy, and with what results will best be learnt from the officers who handled them:—

Behaviour of the Armstrong B.L. guns on active service.

The field guns were first used in China in 1860, and Major T. Milward, R.A., who commanded the artillery of the first division there, gives a favourable account of their efficiency.†

He states:—

In China.

"The guns were sent from England covered with a composition of white lead and tallow, and packed in wooden cases, out of which they were taken when we arrived at Hong Kong, and completely cleaned, and then no more composition was put on them, or cases of any kind; they were generally kept mounted in the hold of the ship, and they were embarked and disembarked in rough weather, and no damage ever received to them of any description.

"At Talienwhan we landed several of them in our ships' boats on a temporary apparatus which we put up ourselves, and in rough weather, but nothing occurred to them. On one occasion my guns had very rough work indeed; we were sent out with a division of the army over a swamp, the very worst ground possible for artillery; the guns were, in fact, almost swallowed up, but we got them through quite safely, and when we came into action we found no damage had been done; everything, including the sights, was covered with mud, but in a few minutes we cleaned that off, and the guns were just as good as ever.

"At 2,000 yards, which was the greatest range we engaged at, our segment shells had great effect, whilst at 450 yards the effect was greater than from common S.B. case shot, but we felt much the want of a common shell with a large bursting charge. On one occasion 24-pr. howitzers set fire to junks which Armstrong guns tried to do and failed.

"The shell acted well with concussion fuzes, but the time fuzes were bad, having been injured on the voyage out from damp. The effect of our shells against earthworks was trifling, owing to the small charge but the segments did a great deal of damage inside the works.

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* For a list of these accidents, as well as the whole state of the question, see "An Historical Summary of the Breech-loading System," by Colonel E. Wray, C.B., R.A., 1870.

† Armstrong and Whitworth Committee, pp. 43, 47.

"During the whole campaign we only fired an average of 200 rounds per gun.

"The vent-pieces were faced once by the armourer serjeants, who effected all the necessary repairs.

"One old pattern vent-piece was blown away."

Lieut.-Colonel John Desborough, R.A., who commanded a division of artillery (one Armstrong battery and one S.B. battery), gives his opinion before the same Committee (p. 50), that an Armstrong battery is not as effective at short ranges as a S.B. battery, but that the Armstrong guns were not sufficiently tried in China to judge of their merits.

Lieut.-Colonel Barry, who commanded the Armstrong battery referred to, reported that, "After having bivouacked for the night at Sangku in "the rain, the breech-screws were nearly completely jammed with "rust." It is to be observed that these were the old pattern breech-screws with square threads; jamming from rust could scarcely take place with the bevel-shaped thread, which has a play of ·02 of an inch.

Major R. J. Hay, R.A., Assistant-Adjutant-General, R.A., in the same campaign, finding that his statements relative to the Armstrong gun were so twisted and distorted by controversial writers in the public press, wrote, 25th March 1861, to Sir Wm. Armstrong, to say that "the Armstrong guns in China rendered the most valuable service, "being always in the most efficient and serviceable condition, although "put to very severe tests. It would have been most surprising if slight "alterations had not suggested themselves in both guns and ammuni- "nition, considering that they were tried for the first time, and that "they were most jealously watched by all."

In New Zealand.

Lieut. Pickard, V.C., R.H.A., who took an active part in the New Zealand campaign, 1861, 3, 4, records his opinion as follows:—

"The Armstrong field guns were always most effective where a long range or great precision was required, and they are therefore in every way an admirable substitute for, and improvement on, the old 9-pr. bronze S.B. guns.

"The great number of times that the Armstrongs were taken to pieces, and the continual rough usage which they met with in embarking and disembarking and in crossing rough country, without sustaining any damage, shows that they are not liable to get out of order from being of too delicate manufacture. They can be loaded and fired very quickly with time and concussion fuzes with well drilled detachments.

"But although the Armstrong field gun has been proved to be an admirable substitute for the 9-pr. S.B. gun, yet it can in no way replace the 24-pr. howitzers which, for obvious reasons, were associated with 9-pr. batteries before the introduction of rifled ordnance."*

A favourable opinion is given also by Colonel E. A. Williams, C.B., who commanded the artillery in New Zealand in 1864:—

"As far as I could judge," he writes, "the Armstrong field guns stood the exposure and rough usage incidental to campaigning wonderfully well.

"The accuracy of their fire was considerable, but I do think that the fuzes are too delicate, or perhaps I should say they require too delicate handling for field guns when under fire.

"We travelled some 6-prs. with columns of infantry, and they were useful in getting long shots at parties of natives, and never impeded the march." †

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* "Proceedings," R.A. Institution, vol. iv., pp. 387–88.

† Letter to Captain Stoney, 1st March 1868.

Let us now see how the Armstrong guns answered for Naval Service.

On the 15th and 16th August 1863 five of our ships were engaged at Kagōsĭma, Japan, and judging generally from the reports forwarded to the Admiralty,* the guns behaved very well; the practice of the 110 and 40-prs. at 4,000 yards was admirable, and the shells with the new pattern Pillar fuzes proved most destructive projectiles, but some jamming of vent-pieces occurred on board the "Euryalus," six old pattern vent-pieces were cracked in 77 rounds, and two instances occurred on board the "Perseus" of vent-pieces having been blown away, in consequence it was supposed of there being no indicators to show that the breech-screw was not properly screwed up. The evil is however incidental to this system of breech-loading. In Japan.

Vice-Admiral Sir Augustus Kuper, the Commander-in-Chief in China at the time, states,† that from observations during this engagement he has formed a very high opinion of the Armstrong guns as regards the precision, force, and destructive power of their projectiles, but he considers the liability of vent-pieces to split or jam, and the care required in screwing them up are great drawbacks to the general efficiency of the Armstrong gun for naval purposes; and when, as at Kagōsĭma, an action is fought in bad weather, the vent-pieces and cartridges are necessarily much exposed to wet, causing serious delay by missfires.

The action of the Straits of Simōna Sek-i had followed that of Kagōsĭma in little more than twelve months, and four of the ships engaged in the second operation were concerned in the first.

"No substantial change had taken place in the ships' armaments, the accidents and defects reported bear, as would be expected, much the same character. No case is reported of a vent-piece having been blown out on this occasion, although a serious escape of gas took place in one instance; a proof, perhaps, of improved training and greater experience. The *matériel*, however, was still of an early date, and not calculated to do justice to the powers of the guns with all the improvements of detail that have been applied within the last two or three years." ‡

The next and last engagement was that of the "Galatea" at Cape Haytien, in 1866, and the guns with all the "improvements of detail" showed their powers to advantage. At Cape Haytien.

"During the time the 'Galatea' was in commission, target practice was carried on satisfactorily with the Armstrong guns, and at Cape Haytien, where they were first tried in earnest, they answered extremely well.

"The forts being some little distance inland, and the range varying from 2,000 to 2,500 yards, they made very accurate practice, and proved themselves to be very superior guns. On this occasion about 80 rounds were fired from each pivot 7-inch B.L. gun, and 20 rounds from each of the two broadside 7-inch B.L. guns.

"The guns kept cool the whole time, and not the slightest accident occurred.

"The same vent-piece was used at each gun the whole day.

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* Ordnance Select Committee Extracts, vol. i., p. 400. The "Extracts from the "Reports and Proceedings of the Ordnance Select Committee," were published regularly every quarter (since 30th June 1862). They contain a well arranged summary of the facts connected with every professional subject discussed by the Ordnance Select Committee; in 1869 the Committee was reorganised and the proceedings are now published under the name of the Department of the Director of Artillery.

† Ordnance Select Committee Extracts, vol. ii., p. 93.

‡ Ibid., vol. iii., p. 23.

"The fuzes did not answer so well, the E time fuze not bursting the shell beyond 1,900 yards, and very often acting prematurely, so that in the latter case, did the ship wish to land men under cover of shell firing, the formidable Armstrong shell could not be used; and in the former case, Pillar fuzes had to be used and acted well at long ranges, though many of these also burst the shells prematurely.

"The 20-pr. is too large for a field gun. It is too heavy and too violent in recoil for boat service, and the ammunition is too complicated.

"The 12-pr. answers extremely well as a field gun." *

From the foregoing testimony it will be admitted that the performance of the B.L. guns was satisfactory on the whole, and fully justified their adoption at the time, although it has since been proved that a less complicated system would be better adapted for general service.

"In short, every power in Europe which took an initiative in adopting rifled field artillery, has had to purchase its experience in a similar manner.

Various changes in Continental systems.

"The present French gun is not the gun of the Italian campaign, and the changes of ammunition have been very numerous. The Austrians adopted the system La Hitte in 1859, changed it for Lenk's system in 1860, and changed again in 1862. The Prussians adopted the Wahrendorf's system in 1860, and changed it for Wesener's in 1863, and have since adopted Krainer's." †

Wedge and shunt guns introduced.

In consequence of the objections urged against his breech-screw guns, Sir William Armstrong introduced not only two natures of wedge guns (40-prs. and 64-prs.) as an improvement on the breech-screw arrangement in points of safety and simplicity, but also 64-pr. *muzzle-loading* guns with *shunt* rifling, and proposed other shunt guns of larger calibre.

As was natural however in this mechanical age and country, Sir William Armstrong was not permitted to bear away the palm without a contest.

The Armstrong and Whitworth system.

Various propositions for rifled guns were submitted to the Ordnance Select Committee, and in 1858 General Peel, the then Secretary of State for War, "called upon Colonel Lefroy, his scientific adviser, for a "report on all the experiments that had been tried on rifled ordnance," and in accordance with the recommendation of that report appointed a special committee to examine as to what was the best rifled gun for field service. This committee came to the conclusion that it was not expedient to incur the expense of trying further experiments with any except those of Messrs. Whitworth and Armstrong.

The trial accordingly took place, but as at that time Mr. Whitworth did not propose any gun of his own construction, and had only rifled government blocks of bronze and cast-iron, the Armstrong breech-loading gun which was complete in every respect was, as we have seen, adopted. Mr. Whitworth nevertheless carried on a series of private experiments, and having perfected his plans, he obtained such good results with his guns that he demanded further trial.

Committee appointed.

A special committee ‡ was then appointed, 1st June 1863, to examine and report upon the different discriptions of guns and ammunition proposed by Sir W. Armstrong and Mr. Whitworth.

* Ordnance Select Committee Extracts, vol. iv., p. 230.

† Ibid., vol. iv., p. 205.

‡ This Committee consisted of Major-General Rumley; Major-General A. J. Taylor, R.A.; Colonel J. W. Ormsby, R.A.; Captain T. Wilson, R.N.; Colonel J. L. A. Simmons, R.E.; Major C. F. Young, R.A.; Commander Singer, R.N.; Mr. J. C. McDonald; Mr. S. Rendel; Major H. S. Dyer, R.A., Secretary.

The inquiry was to embrace the comparative qualities of the several systems with respect to range, accuracy, endurance, ease of working, cost, &c., the fitness, in short, of the guns and ammunition for the various purposes to which ordnance may be applied either in land or sea service.

The committee accordingly made patient and extensive competitive experiments with Whitworth 12-prs. and 70-prs., Armstrong 12-prs. and 70-prs. breech-loaders, and Armstrong 12-pr. and 70-pr. muzzle-loaders; the 12-prs. having been chosen to decide the question for field artillery, whilst the 70-prs. were the best available representatives of heavy artillery, comprising siege, garrison, and broadside guns.

Both natures of the Whitworth guns were muzzle-loaders, and had his well-known hexagonal rifling, and mechanically fitting projectiles.

The 12-prs. were of solid mild steel (having trunnion-rings screwed on to them), with a hoop of the same material over the powder chamber.

The 70-prs. were of the same material, but consisted of an inner tube closed by a cascable screwed in, and strengthened by hoops forced on cold by hydraulic pressure.

The Armstrong breech-loaders were constructed with steel barrels, and with wrought-iron coils superimposed as usual, but the 12-prs. had the ordinary breech-screw arrangement, and the 70-prs. were upon the wedge system.

His muzzle-loaders also had inner barrels of steel; they were rifled on the shunt principle, for projectiles with soft metal studs.

After a searching examination of important witnesses, and complete and comprehensive trials which cost 35,000*l*., the committee concluded their labours, on the 3rd of August, 1865, which is the date of their report.

The results of these experiments were very creditable to both inventors, especially as regarded the construction of their respective guns, each of which after firing about 3,000 rounds was only burst at last by abnormal means.

Conclusions arrived at by the committee.

The report was on the whole most in favour of the Armstrong muzzle-loaders for the following reasons, which among points of the utmost importance to gunnery, the committee established in the course of their experiments:—

"That the many-grooved system of rifling with its lead-coated projectiles, and complicated breech-loading arrangements, entailing the use of tin cups and lubricators, is far inferior for the general purposes of war, to both of the M.L. systems, and has the disadvantage of being more expensive both in original cost and in ammunition.

"That M.L. guns can be loaded and worked with perfect ease and abundant rapidity.

"That guns fully satisfying all conditions of safety can be made with steel barrels strengthened by superimposed hoops of coiled wrought-iron, and that such guns give premonitory signs of approaching rupture; whereas guns composed entirely of steel are liable to burst explosively without giving the slightest warning to the gun detachment."

These remarks are not supposed to be limited to heavy guns, they apply with equal or greater force to field guns; in fact, the committee expressed their opinion that both Sir Wm. Armstrong's and Mr. Whitworth's M.L. systems, including guns and ammunition, are on the whole very far superior to Sir Wm. Armstrong's B.L. system for the service of artillery in the field.

Question of Rifled M.L. Guns for

In 1866 a new committee, consisting of Sir R. Dacres as president, and twelve experienced Royal Artillery officers of high rank, as mem-

Field Service.

R.M.L. guns for field service recommended in 1866.

bers,* was appointed specially to investigate the subject, and they having taken into consideration all the circumstances of the case, came to the conclusion that "the balance of advantages is in favour of M.L. field guns," and recommended their adoption inasmuch as they are equal to breech-loaders in range and accuracy, and much superior to them in the simplicity of their fittings† and ammunition, as well as in their non-liability to go out of order.

A few 12-pr. R.M.L. guns of 8 cwt. were made with wrought-iron and steel similar to the latest pattern for home service, but the authorities nevertheless hesitated to incur the expense of at once re-arming all our field batteries with muzzle-loaders.

After this, another committee, under the presidency of Major-General Eardley-Wilmot, R.A., was appointed in December 1868 to consider the whole question of "Field Artillery equipment for India." But as the authorities considered it necessary that India should be able to produce her own guns,‡ the committee was restricted to bronze as a material. The committee was also directed to adopt a muzzle-loading gun. Accordingly having satisfied themselves by experiments that bronze would answer the purpose, the 9-pr. bronze rifled gun of 8 cwt. was approved for Indian service in May 1870. These guns have since failed when manufactured in numbers, and it has been decided to supply India with iron guns.

Bronze gun for India.

The Dartmoor experiments.

Meanwhile a special committee of Royal Artillery officers (Major-General C. Dickson, C.B., V.C., president) assembled at Dartmoor in June and July 1869 for the purpose of determining the most effective projectiles and fuzes for the B.L. guns, took occasion when writing their report to recommend a field howitzer which should be a muzzle-loader, suitable for high-angle firing and capable of throwing a common shell with a large bursting charge.

On the 25th July 1870 a Special Committee of Artillery officers under Major-General Sir John St. George, K.C.B., as president, was appointed to carry out comparative trials with the 9-pr. bronze rifled gun (Indian pattern) and the 9-pr. and 12-pr. B.L. guns of the home service, and to report fully on the whole subject.

From their report dated 28th November 1870,§ the following paragraphs are extracted:—

"The Committee have no hesitation in giving the preference to the M.L. gun, both in respect to simplicity and facility of repair.

"If, as regards the question of endurance, the Committee are called upon to select between a structure of wrought-iron and steel and one of bronze, as tried by them, they unhesitatingly pronounce in favour of the former, whether the gun be a muzzle-loader or a breech-loader.

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* The members were—

Major-General St. George, C.B.	Colonel Eardley-Wilmot.
" E. C. Warde, C.B.	" Gambier, C.B.
" T. W. Ormsby.	" Phillpotts.
" H. J. Taylor.	" Smyth, C.B.
" C. Dickson, V.C., C.B.	Brevet-Colonel J. Adye, C.B.
Brigadier-General H. Lefroy.	" D'Aguilar, C.B.

Secretary, Brevet Lieut.-Colonel Miller, V.C.

† "Each B.L. battery, in addition to spare articles connected with the breech-loading apparatus, is supplied with a box of facing implements weighing 105 lbs., and containing 25 articles required for refacing the vent-pieces and bush rings, and with a set of special tools in two boxes, together weighing 83 lbs., containing a large number of articles."—Report of the Armstrong and Whitworth Committee, p. xxxi.

‡ See Extracts, Ordnance Select Committee Proceedings, vol. iv., p. 382.

§ Report of Special Committee, 1870, on the relative merits of M.L. and B.L. field guns.

"It may be urged that considerations of manufacture favour the adoption of bronze for M.L. guns for India, but the same cannot be accepted as applying to this country, and taking weight for weight it is impossible to deny that far greater endurance will be attained by the present mode of construction than by the use of bronze.

"The service B.L. system, owing to the absence of windage, necessitates the employment of a mechanical arrangement for lighting the time fuze. This is effected by the employment of a detonator, which has proved to be highly sensible to climatic influences. The M.L. gun on the other hand has the advantage of being able to use an ordinary wood time fuze, which experience has proved to be little at all affected by climate.

"As regards cartridges, the B.L. guns have the great disadvantage of requiring the use of lubricators.

"In respect to other stores, such as percussion fuzes and projectiles. the Committee believe that, whether for breech or M.L. guns, there will be found little or no difference between them so far as regards their capability to bear the tests of travelling or climate.

"Judging from the results of the practice at Aldershot, the 9-pr. M.L. and the 12-pr. B.L. guns appear, in respect to shooting, to be much upon a par; the former being superior in point of shrapnel shell with time fuzes, the latter in point of segment shell with percussion fuzes; the 9-pr. B.L. gun being inferior to both.

"The advantages of simplicity, facility of repair, ease of working, rapidity of fire, original cost, and cost of maintenance, are in favour of a M.L. gun, and the Committee consider that these qualifications outweigh the important advantage of the superior amount of cover given to the detachments when entrenched and in the open, which a B.L. gun affords, and are therefore of opinion that, on the whole, a M.L. gun is the more efficient for war purposes; but they recommend that, if adopted for home service, they be made of wrought-iron with steel tubes."

A wrought-iron muzzle-loader with steel tube recommended for home service.

Since then some batteries have been supplied with wrought-iron R.M.L. 9-prs. of 8 cwt., and it is now intended to arm all the Horse Artillery and half the field batteries at home with this nature of gun, whilst the remaining field batteries at home will have M.L. 16-prs. of 12 cwt.*

* A 7-pr. steel rifled muzzle-loading gun weighing 150 lbs. was used with good effect in Abyssinia, 1867–8, and is the present pattern of "Mountain" gun; previously to that some steel 7-prs. of 190 lbs. were sent to Bhootan, and some S.B. bronze 3-prs. were converted into rifled 7-prs.

SECTION II.—Heavy Rifled Muzzle-loading Guns.

Great importance of heavy ordnance and our progress therein.—Necessity for heavy M.L. guns.—100-pr. and 150-pr. S.B. guns.—Competition to ascertain the best mode of rifling.—The systems of Commander Scott, R.N., Mr. Lancaster, Mr. Jeffery, and Mr. Britton.—The so-called French system and the "shunt."—Recommendations of Ordnance Select Committee.—The "Woolwich guns."—Steps taken to obtain a cheaper construction.—The cheaper or "Fraser" construction. —First trial of 9-inch guns on the cheap plan. Second trial of 9-inch guns and trial of 64-prs. in the meantime.—Adoption of the cheap plan as the service construction.—Bursting of a 9-inch gun of this construction at proof.—Final trial of 9-inch guns and their great endurance.—Present state of the question.

Great importance of heavy ordnance.

Of all weapons of war heavy guns—the armament of our ships and fortresses—are of paramount importance to Great Britain, the integrity of whose empire depends upon the maintenance of her supremacy at sea.

It is gratifying then to know that up to the present at least we hold our own in this respect, for our progress in heavy ordnance has not been surpassed by any nation on the globe.

Our progress in heavy ordnance.

The battles of the Nile, Trafalgar, and all the other naval actions about the beginning of this century, were fought and won with no heavier pieces than 68-pr. carronades of 36 cwt. (for short ranges) and 32-pr. guns of 56 cwt., but if we went to war to-morrow, some of our ships might go into action with guns of 25 tons weight capable of penetrating any hostile ironclad afloat at short ranges; or, if distant firing were required, capable of throwing their 600 lb. projectile into a moderately sized magazine two miles away, whilst before this year (1872) is over we shall have some vessels armed with still more powerful pieces, viz., 700-prs. of 35 tons weight.

This progress of our heavy ordnance will now be traced :—The first marked improvement after Lord Nelson's time, was made about 1830 by General Millar, R.A., the head of the Gun Factories at Woolwich, who introduced the 8-inch and 10-inch shell guns, for horizontal firing. Ten years afterwards, *i.e.*, in 1840, Mr. Monk, chief clerk in the Department, proposed the 42-prs. and 56-prs.; and subsequently to this, Colonel Dundas, R.A., who succeeded General Millar, introduced 68-prs.—a great stride, as it was then thought, in the progress of heavy ordnance, and so indeed it was; but the supremacy of the 68-pr. was not of long duration. It is no longer a heavy or a powerful gun, according to modern artillery ideas. It has been dwarfed by its big rifled brothers of recent date (see Plates IX. and X.).

Necessity for heavy rifled M.L. guns.

It has been stated in the preceding section how the 7-inch B.L. and the 64-pr. M.L. guns were introduced, but although these rifled guns were more powerful than the S.B. 68-prs., they soon became insufficient for the modern requirements of naval warfare, for the power and precision of rifled guns and the growing use of concussion shells which would burst on striking a ship's side and make a hole beyond repair, or having penetrated, would burst between decks, dealing death and destruction around, and probably setting fire to the vessel, necessi-

tated the use of ironclads.* To penetrate these necessitated in turn still more powerful guns, and then commenced the Shoeburyness† experiments of guns *versus* armour plates, which are not yet decided.

The judgment which the Armstrong and Whitworth Committee pronounced in favour of M.L. guns was only in accordance—so far at least as heavy guns were concerned—with the preconceived opinion of our leading artillerists, for any B.L. arrangement with guns using the enormous charges required would not only be too cumbrous but actually unsafe.‡

As the striking effect of a projectile depends more on its velocity than on its weight, and as a round shot fired from a S.B. gun has considerably greater initial velocity than an elongated shot fired from a rifled gun, owing to the friction in the bore of the latter, as well as to its smaller proportionate charge, the Admiralty at first proposed wrought-iron S.B. guns of large calibre to penetrate armourplated vessels at close quarters. Accordingly in 1864, after mature experiments, two natures of wrought-iron S.B. guns were adopted; these were the 100-pr. of 9″ calibre, and 150-pr. of 10·5″ calibre. They were built up on the Armstrong coil principle, but only about fifty of the former and a dozen of the latter were made, as it soon became evident that still more potent guns were necessary, and that we could make them too in the shape of wrought-iron R.M.L. guns. In fact such good results were obtained from the 64-pr. M.L. shunt gun (which was approved as a sea service gun, March 10, 1865), as well as from larger experimental guns on the same system of rifling and construction, that the Ordnance Select Com-

100-pr. and 150-pr. S.B. guns.

* The power of horizontal shell fire was perceived only 40 years ago; the French then adopted the Paixhans shell gun, and General Millar, R.A., introduced our 10-inch and 8-inch shell guns; the new species of fire, however, lay dormant for many years, but at length woke up by war, its development advanced *pari passu* with that of rifled ordnance. Nearly all the naval engagements which have taken place of late years furnish instances of the destructive effect of shells on wooden vessels:—

At Sinope, during the Crimean war, the Turkish fleet was actually destroyed by Paixhans' explosive shells fired from the Russian vessels "Constantine" and "Paris."

In the recent American war the ironclad "Merrimac" blew up by shell the wooden vessel "Congress," having first made dreadful havoc of the crew; and the "Kearsage" sunk the "Alabama."

Lastly, at Lissa the Italian vessel "Palæstro" (partially plated) was destroyed by the Austrian shells.

† Shoeburyness, situated on the upper bank of the mouth of the Thames, was a Danish encampment in the 9th century, but was unknown in modern times, save as a lonely coast guard station, till purchased by Government for an artillery practice ground on account of the long range afforded by its stretching sands. In 1849 the first gunnery practice took place there and "Shoeburyness" then comprised only 8 acres of upland occupied by two officers and a gun detachment; but field by field was purchased according as the science of artillery progressed, and there are now 216 acres of upland and 6,512 acres of sands, Government property. A straight row of pegs extends for 10,000 yards along the sands, and at the ebb of certain tides a range can be measured and the shot recovered up to 12,000 yards, seven miles say.

On the 1st of April 1859 "the School of Gunnery" was established with a commandant and numerous staff, a number of officers and non-commissioned officers of the Royal, Militia, and Volunteer Artilleries undergo a course of training there annually, whilst the experiments which are carried on there with guns and armour plates attract the attention of the scientific and artillery world.

‡ There is no doubt that large B.L. guns, if they could be made sufficiently safe and simple, would be very superior to muzzle-loaders for certain purposes, such as casemate, broadside, and cupola, and perhaps too in connexion with Captain Moncrieff's new "lift" gun carriage. The fact is, that a breech-loading arrangement on a small scale, as in revolvers, infantry rifles, &c.—hand weapons in short—is very convenient and satisfactory, but the difficulty of obtaining ease of manipulation and complete gas-tight mechanism increases with the size of the piece, and hence it is that while a breech-loading arm is preferred by Infantry, a muzzle-loading gun is preferred by Artillery.

mittee suggested (Report No. 3553, 25/11/64), that the above two natures of S.B. guns should be also rifled on the shunt system.*

But the shunt rifling itself was eclipsed in 1865 by the "Woolwich" system, and as the steps which led to this result throw considerable light on the whole system of rifling, they are briefly referred to :—

Competition to ascertain the best mode of rifling.

By instructions first received from Lord Herbert in 1859, the Ordnance Select Committee carried on an extensive trial of cast-iron 32-pr. guns rifled for different gentlemen in accordance with their respective views of the best way of rifling the existing store of S.B. cast-iron guns.

The result of this competition, upon which the Ordnance Select Committee reported 3rd February 1863, proved that cast-iron was altogether too weak and precarious a material for rifled guns.

The trial was then extended to wrought-iron guns, rifled on the respective systems of Commander R. A. E. Scott, R.N., Mr. Lancaster, Mr. Jeffery, and Mr. Britten, who with Messrs Lynal Thomas, Haddan, Nasmyth, and Whitworth, were rivals in the cast-iron competition.

At the request of the Ordnance Select Committee, a gun rifled with French grooves was added, and finally a shunt gun also was tried in comparison with the others.

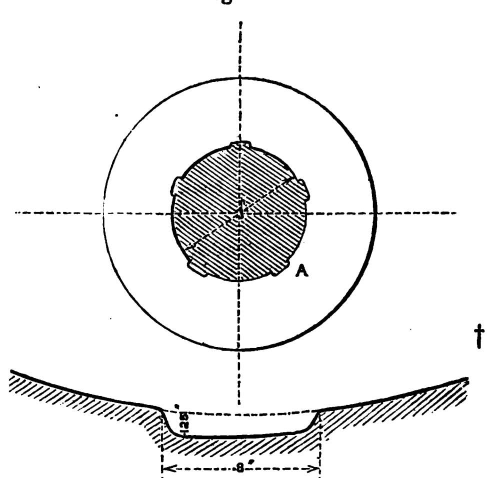
All the guns selected for competition were 7″ R.M.L. guns of 7 tons, built on the Armstrong coil principle, and having inner barrels of steel.

Commander Scott's system.

Commander Scott's gun was rifled in five grooves, which were shallower on the loading side than on the driving side, which was curved with a view to obtain a perfect centring for his shot. His rifling had a uniform spiral of one turn in 294 inches. Fig. 1.

His projectile at first had simply five iron ribs, with two very small copper studs inserted in the driving face of each, but afterwards the ribs were faced with zinc.

Fig. 1.



* These guns, however, remained as they were, the Superintendent Royal Gun Factories having pointed out that they were much too weak longitudinally for rifled guns, an opinion which has since been verified, two of the S.B. 150-prs. having blown the breech out during practice.

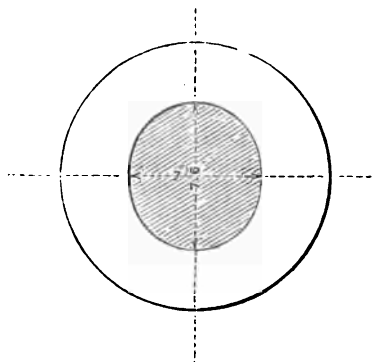
The 150-prs. are now obsolete, and the 100-prs. are used by the navy for drill purposes only.

† The sections of the several grooves are full size, those of the muzzles are on a scale of one-eighth.

Mr. Lancaster's

Mr. Lancaster's gun was oval bored, the major axis being 7·6″, and the minor axis 7″. The rifling making one turn in 360″. Fig. 2.

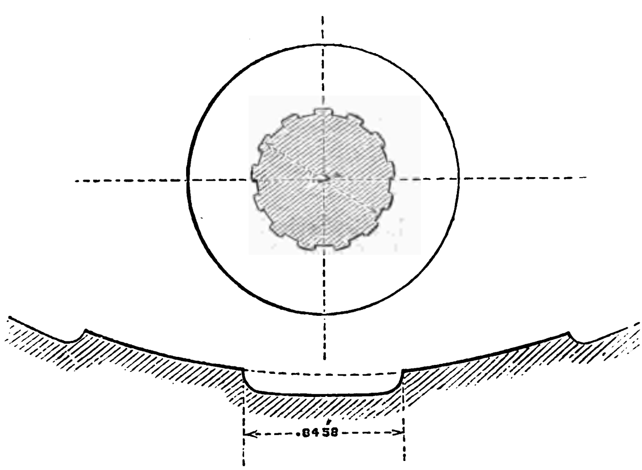
Fig. 2.



Messrs. Jeffery's and Britten's.

One gun was sufficient for Messrs. Jeffery and Britten, as their systems differed from one another only in manner of applying lead to the base of the projectile so that it might take the rifling.* This gun had 13 grooves 0·10″ in depth, and 0·846″ in width, and a turn of 1 in 805″. Fig. 3.

Fig. 3.



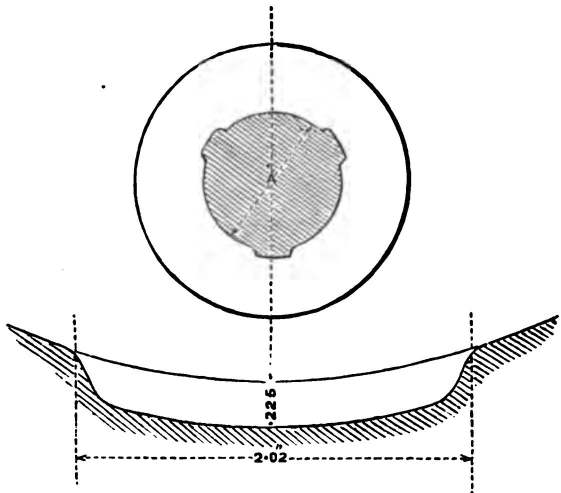
The French gun.

The French gun was rifled in three grooves 0·225″ deep, 2·02″ wide, the rifling gradually increased from nothing at the breech to 1 turn in 259″ at the muzzle. The first batch of projectiles for the French gun had three large half-zinc studs in front, supported by an iron back, and three small ones behind, but as the experiments went on it was found expedient to adopt Major Palliser's proposal of changing the metal of

* Mr. Britten's method of attaching lead coating chemically was adopted for the projectiles of the Armstrong B.L. guns, and has proved most satisfactory.

the studs to gun-metal, and of reversing the position of the studs by placing the smaller ones in front. Fig. 4.

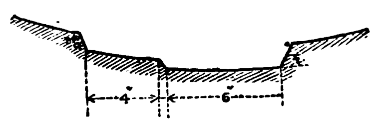
Fig. 4.



The shunt gun.

The shunt gun had six grooves of the well-known form; the spiral was uniform with one turn in 266″ or 38 calibres. The shot had 30 studs, *i.e.*, five for each groove. Fig. 5 shows section at muzzle.

Fig. 5.



All the projectiles had hemispherical heads. The weight of each shell (filled) was 100 lbs. and of each shot 110 lbs., except that of the French shot which weighed only 100 lbs.

A very short experience showed that the systems of Messrs. Jeffery and Britten were unsuited for heavy charges; large pieces of lead were blown off the shot, and the shooting was so wild as to throw these systems entirely out of the competition, which therefore was limited to those of Scott, Lancaster, the French, and the shunt.

Recommendations of O.S.C.

Experiments were carried on which tested these competitive guns in all the cardinal virtues of ordnance, and though the shooting qualities were alike, the Ordnance Select Committee in their final report, No. 3730, dated 1st May 1865, recorded their unanimous opinion in favour of the so-called French system:—

(1.) "Because of the simplicity of its studding on the projectiles.

(2.) "The simplicity of the grooving of the gun, and

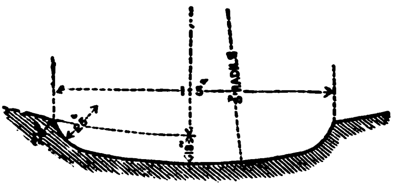
(3.) "From a disposition to admit the advantages of an increasing over a uniform spiral."

And further, the Committee recommended "that the heavy 7″ guns " then in course of manufacture should be rifled in the same manner " as the competitive so-called French gun, except that the width and " depth of the grooves should be slightly decreased, and that 8″ and 9′

"guns also should be completed with similar rifling." * Fig. 6 shows a section of the modified groove.

The modified groove.

Fig. 6.



This was the origin of those powerful pieces of ordnance known by the comprehensive term of "Woolwich guns," and which then meant "wrought-iron M.L. guns built on Sir William Armstrong's principles "improved by Mr. Anderson's method of 'hooking' the coils, and with "solid-ended steel tubes toughened in oil and rifled on the French "system, modified as recommended by the Ordnance Select Committee "for projectiles studded according to Major Palliser's plan."

The Woolwich guns.

The Woolwich guns manufactured on this "original construction," were so far as strength and efficiency were concerned, nearly all that could be desired, but their expense, 100*l.* a ton in round numbers was a serious point, and as it was evident several large guns would be required, the Secretary of State for War, had so far back as October 1864, drawn the attention of the Ordnance Select Committee to the desirability of obtaining some cheaper mode of construction. Colonel F. A. Campbell, R.A., who succeeded Sir W. Armstrong as Superintendent Royal Gun Factories in 1863, being applied to by the Committee set practically and patiently to work out the desired object. Two questions presented themselves for solution.

(1.) Could not a coarser and cheaper iron be obtained which would be sufficiently strong for the exterior of the gun?

(2.) Could not the guns be constructed in a simpler and cheaper form?

By personal visits to most of the leading ironmasters, and a series of experiments, Colonel Campbell had already found a very superior and satisfactory iron for the inner barrels of B.L. guns,† and by following up his success he now obtained a very cheap iron sufficiently strong for the exterior of our heavy guns, whilst in the plan of construction proposed by Mr. R. S. Fraser, C.E., of the Royal Gun Factories, he discerned a solution to the second question.

Mr. Fraser's Construction.

In April 1867, the plan proposed by Mr. Fraser and recommended by Colonel Campbell superseded the original or Armstrong construction. The difference between the two constructions being fully explained in subsequent sections, it will be sufficient to state here that the "Fraser" is a modification of the Armstrong system, and differs from it chiefly in building up a gun with a few double or triple coils instead of several finely finished single ones.

But it will be naturally asked, is this cheap construction as strong as the old one?

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* See extracts from "Proceedings, Ordnance Select Committee," vol. iii., p. 154, or "Proceedings" Royal Artillery Institution, vol. iv., p. 410.

† Previous to the adoption of Marshall and Mills charcoal iron for inner barrels, two barrels out of every three were rejected for defective welds, blisters, &c. and Mr. John Anderson, the then Assistant Superintendent Royal Gun Factories, was obliged to have recourse to the questionable expedient of forming inner barrels from solid forgings.

To answer this question in a most satisfactory form, it will be better to refer to the theoretical grounds discussed in Chapter II., and simply to state here the facts of the case gathered from the trials of strength to which both systems were subjected, and then leave the reader to judge for himself.

First trial of 9-inch guns on the cheap plan.

Colonel Campbell, being officially applied to, explained that it was quite possible to reduce the expense hitherto incurred in the construction of wrought-iron guns by the employment of steel with external coils reduced in numbers, and forged from iron of a cheap quality,* and subsequently he submitted tracings of two 9-inch iron guns on this plan, one with a steel barrel and one with a wrought-iron barrel; but both had breech-pieces, and the *D* and *C* coils were not hooked together. The tracings were approved, and he was directed to manufacture the guns accordingly, 21st October 1864.

They were tested in 1865, and from the result of the previous trials, the Ordnance Select Committee reported † that the guns of cheap construction were not inferior in strength to those on the more expensive mode; but recommended further trials with 9-inch guns including those on a newer plan without forged breech-pieces, which Mr. Fraser, from the experience recently gained, was led to submit.

64-pr. *B* and *D* guns tested in the meantime.

But in the meantime the navy were crying out for cheap 64-prs. and two "Fraser" guns were tested to destruction, to ascertain whether either pattern would answer. One (Expl. No. 320) was known as the *B* pattern (see Mark II., Plate II.), the other (Expl. No. 317) as the *D* (see Mark III., Plate II.).

These experimental guns fired each 2,000 service rounds (charge 8 lbs.), and abnormal charges being then used, the *B* gun burst into 38 pieces, after a total number of 2,270 rounds, and the *D* gun after 2,211 rounds blew out its inner barrel, leaving the breech portion on its carriage, and still sound.‡

Adoption of the cheap plan as the service construction.

The great success of the cheap construction, thus displayed by these 64-prs., combined with its favourable progress in the 9-inch guns under trial, induced the Ordnance Select Committee to recommend (7th December 1866) that half the guns for 1867–8 should be on the Fraser method, and it was subsequently approved by War Office and Admiralty, that all the guns estimated for that year should be on this plan.

During the years 1867-8 many of the cheap guns had been proved and issued for service, the majority being on the pattern of Expl. No. 330—*i.e.* with a steel tube, and reinforced with a triple breech coil (Mark III., Plate VI.).

Bursting of a 9-inch gun at proof.

Of the 9-inch guns alone about 100 had passed proof, and the soundness of the system was generally recognised, but on the 25th of September 1868, a 9-inch gun of that pattern burst violently the first round of proof, and the circumstance created some surprise, as it was commonly believed that a coiled wrought-iron gun would not burst explosively, but the authorities knew well that instances had already occurred of their doing so; for instance, the 9·22-inch of original construction before alluded to burst in this manner with a service charge, and two 40-pr. B.L. guns actually went to atoms whilst proving vent-pieces; these guns were no doubt old and worn out, and had given timely indications of their dangerous condition, but

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* Extracts from "Proceedings of Ordnance Select Committee," vol. ii., p. 230.
† Ibid., vol. iv., p. 192.
‡ Extracts from "Proceedings of Ordnance Select Committee," vol. iv., p. 356.

it was also known that new guns would go in the same manner if their elasticity or strength were subjected to a too sudden or a too excessive strain, such as that exerted by the action of some violent explosive like gun-cotton or nitro-glycerine, or from an intolerably large charge of powder. Now, there is no doubt that the bursting of the 9-inch gun at proof was principally due to a defective tube, and it was no wonder that the powerful proof charge (53¾ lbs.)* should have blown it to pieces at the first round.

To prevent, however, a similar occurrence, steel tubes for heavy guns are now subjected after toughening to a water pressure on the interior of 8,000 lbs. per square inch, which is sufficient it is thought to detect any latent cracks. Any gun that has stood the proof may safely be relied on as free from these dangerous defects.

Final trial of 9-inch guns.

In order to set the matter at rest, further trials with two cheap 9-inch guns were recommended and approved.

No. 332, with a steel tube two inches thick, and reinforced with two double coils, survived the ordeal. No. 368, with a steel tube three inches thick, and reinforced with one massive triple coil, did not it is true complete the test, but it refused to yield although its tube was split at the 1008th round.

The result was deemed most satisfactory, not only because the steel tube failed gradually, but because the great strength of the outer fabric—the point at issue—was proved beyond all doubt by the gun actually firing 41 rounds after the tube was split through, and yet remaining sound exteriorly. (For details see Ordnance Select Committee's Proceedings, 1869.)

In fact both guns behaved so exceedingly well under trial that the authorities were left in the dilemma of not knowing which pattern to choose.

They, however, decided on constructing 7-inch and 8-inch guns as before, on the No. 368 type, but to make 9-inch guns and upwards on the No. 332 type.† .

Present state of the question.

The question then stands thus :—Up to April 1867 all our heavy guns were made on the original construction, like the 9-inch gun, Mark I. (*see* Plate VI.), and from that date up to August 1869 nearly all have been made like the 9-inch gun No. 368, or Mark III.—*i.e.* consisting only of four parts, viz. steel tube, cascable, *B* tube, and breech coil—and 7-inch and 8-inch guns are still to be made in the same way.

The alteration which then took place in the manufacture for 9-inch guns simply consists in having a thinner steel tube and two coils on the breech (*see* Mark IV. and V., Plate VI.), instead of one triple one; or perhaps the difference in construction will be more readily remembered by using the familiar illustration, and saying that in the former instance the steel tube is enveloped in "jacket and trousers," whilst in the latter it is thinner, and has "jacket, waistcoat, and trousers." The higher natures are made in the same way, but have a "belt" in addition.‡

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* R.L.G. powder.

† This pattern costs about the same as the other, the extra expense of making two breech coils being compensated for by the lighter steel barrel. Good reasons for preferring this construction for heavy guns would be that the inner coil can be made of twice rolled (*i.e.* superior) iron, and with greater perfection, and also that the thinner the tube the more will it be compressed by the shrinking, and strengthened accordingly.

‡ See extracts from Proceedings of the Ordnance Select Committee for 1864–9.

In conclusion, it may be remarked that the tests and trials bearing on this question, while exemplifying the pains taken to obtain the best war *matériel*, cannot fail to satisfy the most sceptical that the present construction of our guns is sound and durable, and also that we have made marked progress of late years in heavy ordnance. But this progress in the production of heavy ordnance cannot be fully appreciated unless the difficulty of perfecting a more powerful gun than previously existed is properly considered and understood. In the first place, the practicability of manufacture and the durability of structure must be ascertained. The weight, calibre, length, system of rifling, weight and shape of projectile, &c., &c. must be all scientifically calculated so as to ensure excellence in range, accuracy, and penetration; and then each and all of these constructional details are liable to alteration should the thorough trial of a specimen gun at Shoeburyness render any amendment advisable.

CHAPTER II.

THE THEORY OF GUN CONSTRUCTION.*

Strength of a gun not proportional to its thickness of metal.—Strength of any cylinder limited by the quality of the material.—Two distinct principles of construction.—Barlow's formula.—Hart's.—Armstrong's system.—Whitworth's.—Palliser's.—Rodman's.—Armstrong's principles of construction.—Explanation of the terms "shrinkage," "tension," &c.—Circumstances which regulate the shrinkage.—Shrinkage cannot be carried out with theoretical precision.—The Armstrong construction as modified by Mr. Fraser.—The excellence of our heavy Ordnance.—Our own and foreign guns compared. Hooped cast-iron guns.—Steel guns.—Krupp's establishment at Essen (*footnote*).—The American smooth-bores.

When rifled ordnance first came into fashion and the artillery service required guns in which the maximum of strength would combine with the minimum of weight, various plans of construction were proposed and the inventors generally adduced theories in support of their several systems. Mathematicians, too, turned their attention to the problem, so that altogether a good deal—judging by quantity—has been written and spoken on the subject of late years. The present chapter is an attempt to explain, as briefly as possible, the science of constructing guns, and to show by reference to modern ordnance how far theory is carried out in actual practice :—

Strength of a gun not proportional to its thickness of metal.

The power of any homogeneous tube or cylinder to resist pressure from within is not proportional to its thickness. A cylinder for an hydraulic press with a thickness equal to half the diameter of the piston is said to be nearly as strong as one ten times as thick. Guns are no exception to the general rule. The sides of the 13-inch S.S. mortar are twice as thick as those of the 13-inch L.S. mortar, but the former piece is far from being twice as strong as the latter.

Strength of a cylinder limited by the quality of its material.

Several men of science who investigated the problem agree that "no "possible thickness can enable a cylinder to bear a continual pressure "from within greater on each square inch than the tensile strength of "a square inch bar of the material;" that is to say, if the tensile strength of cast-iron be 11 tons per inch no cast-iron gun however thick could bear a charge which would continually strain it beyond that point, for on the first round the interior lamina would be ruptured before the outer portion could come into play, and every succeeding round would tend to magnify the evil. Now these statements lead us to two distinct principles on which the whole science of constructing guns may be based :—*First*, that not only must the whole gun be sufficiently powerful to withstand repeated firing, but the material of the inner barrel must be strong and hard enough to bear the successive strains of discharge ;

Two distinct principles.

* This chapter is an enlarged edition of a paper originally published by Captain Stoney in the R.A. Institution Proceedings.

The following works are recommended to the reader who wishes to study this subject more fully.

"The Construction of Artillery," by Robert Mallett. London: Longman & Co., 1856, and "Ordnance and Armour," by Alexander L. Holley. New York. 1865.

and, *Secondly*, that the gun should if possible be constructed in such a manner that each part of its mass would come into play, or do its due proportion of work at the instant of firing.*

A greater strain on a rifled gun than on a smooth-bore.

The first principle is self-evident, and so indeed is the necessity for making rifled guns stronger than smooth-bores, but it will perhaps be well to state that the greater the weight and the length of a projectile, the greater is the opposition from inertia and friction which it offers in the bore to the expansion of the ignited charge. This opposition is considerably augmented if the projectile is constrained to travel through the bore in a spiral course, hence it is not difficult to comprehend why a rifled gun must needs be of a stronger, tougher, and more elastic material than a smooth-bore gun, in which the round shot yields promptly to the first impulses of the powder gas (to which it presents half its surface), and bounds freely forward through the bore almost unimpeded by friction, while the strain on the gun is immensely relieved by the comparatively great windage. Again, as the explosive power† of a cartridge as well as the inertia and friction of a projectile increase with their respective weights in a cubical ratio, whilst the surface of the chamber and the base of the projectile, against which the powder-gas acts, increase only in a square ratio, it follows that the larger the charge and the weightier the projectile the harder and stronger must be the inner barrel, or else the slower must be the combustibility of the powder used.

With regard to the second principle it is easy to show that in the case of an ordinary homogeneous gun the inner portions receive the brunt of the explosion while the outer portions are hardly affected by it at all, and consequently that there is a certain amount of dead weight about every homogeneous gun. Take for example a section of a 10-inch cast-iron gun where the thickness of the metal is 5 inches, and assume that the amount which the metal will stretch before it breaks is a thousandth part of its length. Now supposing a pressure could be communicated with undiminished force throughout the mass, it is plain that when the circumference of the bore would be stretched a thousandth part of its diameter, *i.e.* the hundredth of an inch, the lamina an inch further would be only stretched $\frac{10}{12}$th of that amount, and the lamina an inch further still only $\frac{10}{14}$th, and so on to the external lamina which would be only stretched $\frac{10}{20}$th or half the amount, that is, when the interior of 10 inches diameter would be on the point of rupture the exterior of 20 inches diameter would have only half the strain on it which it could bear. Hence, we might lay down the law that the resistance of each lamina varied inversely as its distance from the axis; but every one knows a pressure is not transmitted with undiminished force through any solid, but that it rapidly decreases as it travels forward, and therefore that the opposition which the exterior is called upon to supply must be less than that deduced by the foregoing law. In fact, the resisting power of the material as well as the distance from the axis must be taken into consideration.

What then is the law or formula according to which a gun should be so constructed that its resistance to the shock of the discharge should be equally distributed throughout its mass? It is not exactly known. According to the late Professor Peter Barlow, F.R.S., the power exerted by the different parts of a metal cylinder varies inversely as

Barlow's formula.

* More correctly the instant at which the greatest strain is on the gun, and that would appear to be just before the inertia of the projectile is overcome.

† The intensity of the heat too generated by the explosion probably increases with the bulk of the charge.

the square of the distances of the parts from the axis; in other words the strains (σ and s), on any two laminæ are inversely proportional to the square of their radii, (ρ and r), or

$$\frac{\sigma}{s}=\frac{r^2}{\rho^2}.$$

Dr. Hart, Fellow of Trinity College, Dublin, having taken into account the extensibility and compressibility of the metal, which Barlow appears to have omitted, calculated that there is a greater strain on the exterior. His formula may be written thus,— Hart's.

$$\frac{\sigma}{s}=\frac{r^2}{\rho^2}\,\frac{R^2+\rho^2}{R^2+r^2}.$$

R and r being the external and internal radii, ρ the radius of an intermediate lamina of which σ is the strain, and s the strain on the inside.

If we want to compare the strain on the inside with that on the outside, $\rho=R$, and we have by inversion,—

$$\frac{s}{\sigma}=\frac{R^2+r^2}{2r^2}.$$

In the case of 10-inch gun before referred to, the strain on the interior compared with that on the exterior, would, according to Barlow, be as 100 to 25, or 4 times as great, but according to Hart only as 125 to 50, or $2\frac{1}{2}$ times as great.

But although the law is not precisely known, all successful gun builders endeavour to follow its general principle, and we thus find it partially carried out:—

In ARMSTRONG's B.L. guns by giving, through means of shrinking, greater tension to the outer coils than to the inner ones, so that the former do a certain amount of work in compressing and energetically supporting the latter, and still more in his M.L. guns by the employment in addition of a stronger material (steel) for the inner barrel. Armstrong's system.

In WHITWORTH's, where a similar effect is produced by forcing on the outer tubes by hydraulic pressure. Whitworth's.

In PALLISER's, by making the barrel of a stronger material than the outside. Palliser's.

In the RODMAN plan of casting adopted by the United States in which the hollow casting is cooled from the interior, so that the inner portion is compressed and supported by the contraction of the outer portion around it. Rodman's.

The last method approaches nearest of all perhaps to the fulfilment of the principle as the metal becomes gradually stronger and stronger from the outside to the bore, whereas in all the other systems the strength of the metal does not progress gradually by regular increments but *per saltum* according to the number of parts superimposed. Unfortunately, however, cast-iron even though thus scientifically disposed is naturally too weak and brittle as a material for rifled ordnance; but it is not impossible that safe, powerful, and cheap guns may yet be made in this manner of an improved description of steel.

To Sir William Armstrong is due the merit of employing wrought-iron coils shrunk together. His main principles of gun architecture consist essentially:— **Armstrong's principles of construction.**

First, In arranging the fibre of the iron in the several parts so as best to resist the strain to which they are respectively exposed; thus, the walls or sides of the gun are composed of coils with the fibre running round the gun so as to enable it to bear the transverse strain of

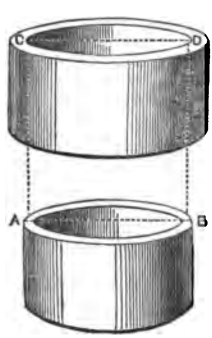
discharge without bursting, whilst the breech end is fortified against the longitudinal strain, or tendency to blow the breech out, by a solid forged breech-piece with the fibre running along the gun.

Secondly, In shrinking the successive parts together so that not only is cohesion throughout the mass ensured but the tension may be so regulated that the outer coils shall contribute their fair share to the strength of the gun in accordance with the theory already explained.

With regard to the first principle a gun may be destroyed either by the bursting of the barrel or by the breech being blown off. Now, wrought-iron in the direction of its fibre is about twice as strong as it is in the cross direction, hence the best way to employ it to resist the transverse strain is to wrap it round and round the piece like a rope. This is the foundation of the Armstrong coil system. For the same reason the best way to resist the longitudinal strain is to place the fibre lengthways or end on; so a breech-piece was made from a solid forging with the fibre in the required direction.

Explanation of the terms "shrinkage," &c.

To explain the second principle it will be first necessary to define the terms "shrinkage," "tension," and "compression," as here employed.



When two coils are prepared for shrinking, that is, when their surfaces which are to be in contact are brought to their proper dimensions and to the necessary degree of smoothness, the excess of the exterior diameter *AB* of the inner one above the interior diameter *CD* of the outer one, both coils being cold, is termed the "shrinkage."

In order to shrink the two together, the outer coil must be expanded by heat* until it is large enough to drop over the inner one where it is allowed to cool and contract. Now the power of heated metal to resist contraction is less than that of cold metal to resist compression to a certain point and to a certain point only, hence the inner coil becomes compressed in the process, and the amount its diameter *AB* is decreased thereby is called the "compression," whilst the outer one remains partially extended, and the amount by which its diameter is thus increased beyond its original and natural length *CD* is its "tension."

The shrinkage is equal to compression *plus* the tension, and the amount must be regulated by the known tension and compression under certain strains and circumstances.

The tension on a coil when shrunk on should in no case exceed that due to the elastic limit of the iron. The elastic limit of bar iron is about 12 tons per square inch and causes an extension of about $\frac{1}{1000}$th of its length,† any weight beyond this would stretch the iron permanently and weaken the fibre. Hence the tension on no coil should exceed $\frac{1}{1000}$th of its diameter.

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* 500 F. is quite sufficient; this will allow a working margin of expansion beyond the amount calculated, so that the iron need never be raised to the high temperature at which scales form (see page 47).

† The amount of elongation varies not only on the quality of the metal, but with the size and shape of the specimen tested. The specimens tested in the Royal Gun Factories' machine are two inches long and stretch from ·003″ to ·004″ at the limit of elasticity, but from the experiments quoted by Mr. Kirkaldy (Experiments on Wrought-iron and Steel, p. 66) made from a bar of iron 10 feet long and 1 inch square, the extension was only $\frac{8}{100000}$th of the length, for every ton, per square inch of section up to the elastic limit, after which it rapidly increases up to the breaking strain.

The compression varies inversely as the density and rigidity of the interior mass, the first layer of coils will therefore undergo more compression than the second, and the second more than the third, and so on. Accordingly, in the Armstrong or original construction, a greater proportion of shrinkage was given to the inner layers than the outer, because so much of it was absorbed by compression. The shrinkage, however, never exceeded ·002 per inch of diameter. Much too will depend on the thickness and strength of the coil to be shrunk on; for the heavier it is, the tighter will be its grip, and the more will the inner parts be compressed and supported, whereas a thin weak coil, if shrunk on the same mass, would probably suffer from over tension. In the Fraser guns of present construction the heavy breech coil compresses the steel barrel to such an extent that the latter becomes in some instances as much as $\frac{1}{100}$th of an inch smaller in diameter during the process of shrinking,* whilst one or two instances have occurred of the thin exterior coils in large guns of the original construction splitting during practice, and thus indicating that they were strained beyond their strength (see page 176).

Circumstances which regulate the shrinkage.

The position of the coil must be also considered. The shrinkage over the seat of the charge is greatest of all, as that part of a gun must be the strongest and firmest, whilst the shrinkage over the muzzle is the least for an opposite reason.

Shrinkage not carried out with theoretical precision.

Add to all the foregoing conditions the expediency of shrinking on the several parts so that each shall do its proportion of work on the discharge of the piece (according to a law not exactly known), and it will be seen that the problem is a very difficult one to solve in practice. Indeed Sir William Armstrong, who introduced the system, has admitted that he did not carry out his plan with theoretical precision, but that the coils were simply shrunk together sufficiently to secure the stability of the fabric and that a small variation was immaterial.† His primary object therefore was to secure cohesion throughout the mass,

* TABLE showing CONTRACTION by shrinking and EXPANSION by proof, on the bore of a steel tube for a 10-inch R.M.L. gun.

——	Diameter of bore. Before Shrinking on Breech Coil.	Diameter of bore. After Shrinking on Breech Coil.	Contraction.	Diameter of bore After proof.	Expansion.
	inches.	inches.	inch.	inches.	inch.
At 90 inches from muzzle	9·998	9·998	—	9·998	—
„ 101 „ „	9·998	9·995	·003	9·995	—
„ 104 „ „	9·998	0·994	·004	9·994	—
„ 107 „ „	9·998	9·994	·004	9·994	—
„ 110 „ „	9·998	9·991	·007	9·994	·003
„ 113 „ „	9·998	9·99	·008	9·992	·002
„ 116 „ „	9·998	9·988	·01	9·99	·002
„ (118 „ end of rifling)					
„ 119 „ „	9·997	9·987	·01	9·99	·003
„ 122 „ „	9·999	9·99	·009	9·991	·001
„ 125 „ „	9·999	9·99	·009	9·991	·001
„ 128 „ „	9·999	9·991	·008	9·991	Nil.
„ 131 „ „	9·998	9·993	·005	9·995	·002
„ 134 „ „	9·998	9·994	·004	9·996	·002
„ 137 „ „	9·995	9·991	·004	9·993	·002

† Report on Ordnance, 1863, p. 162. "Construction of Artillery," Inst. Civil Engineers, 1860.

and in doing this within the limits of shrinkage before stated, he built up his gun to a certain extent in accordance with theory.

It is at all events certain that by a combination of his two principles, one of Sir William Armstrong's guns is considerably stronger than a gun of the same shape and weight would be if made out of a solid forging like the Horsfall gun.

The Woolwich guns built on his system, and lined with toughened steel, are sound and strong, but from the fine iron used and the great number of exquisitely finished coils and a forged breech-piece, their manufacture was very costly; and as it was probable that several heavy guns would be required, the War Office pointed out the desirability of procuring some cheaper plan. Accordingly, as already stated, the attention of the Royal Gun Factories was devoted to the question, and their efforts have been crowned with success. First, a cheaper iron sufficiently strong for the exterior of the gun was obtained, and secondly, the plan proposed by Mr. Fraser, the principal executive Officer of the Department, was found to be less expensive than the original one.

Mr. Fraser's modification.

Mr. Fraser's plan is an important modification of Sir. W. Armstrong's, from which it differs principally in building up a gun with a few long double or triple coils, instead of several short single ones and a forged breech-piece. There is less material, less labour, and less fine working, and consequently less expense required for the "Fraser" or present service construction (see Marks I. and III., Plate V.).

With respect to theory it may be urged in its favour, in the first place, that a forged breech-piece (which is a comparatively expensive article and liable moreover to fly into fragments should the gun burst) is not required with a solid-ended steel barrel and long thick coils, although it is absolutely necessary with several short coils to compensate for the longitudinal weakness of their several joints, or with open ended tubes. The whole of the wrought-iron therefore in a Fraser gun can be coiled round the barrel, and thus extra transverse strength will be gained as well as extra compression at the breech end. Moreover, the trunnion-ring which was simply *shrunk* on in the original construction is *welded* to the breech coil in the Fraser construction, so there is no fear of the slipping which sometimes took place in the early Armstrong guns. And in the second place, although a series of thin coils help us to distribute equally the induced strain on a gun by shrinking on each coil separately, the method is open to the serious objection that it is practically difficult to calculate the respective proportionate amount of tension, and consequently the greater the number of pieces in a gun, the more likely some weakness will exist in the mass owing to the undue strain on some of the parts; for instance, a 13-inch gun of original construction (Experimental No. 300), split some of its outer coils while the interior ones remained uninjured, thus clearly proving that there was too great strain on the former (see page 176).

Thus far for theory, but the proof of a gun is in the firing it can sustain, and the results of the thorough trials referred to in Chapter I. show beyond all doubt that our present construction is as strong, if not stronger, than its original type.

The excellence of our heavy ordnance.

In the face of all the improvements which have lately taken place in metallurgy and mechanical appliances, it would be rash to say that we have reached perfection in the construction of guns, but it may be asserted without fear of refutation that we possess the safest,* cheapest, and simplest system of heavy ordnance in existence.

* The main merit of our guns is their non-liability to burst explosively, and that if a gun fails at all it will in all probability give timely warning to the gun detachment, of course we have not tried them yet in the heat of action, but it is very unlikely they would fail us in that hour of need.

At this point it may not be uninteresting to allude to the heavy ordnance of foreign nations in comparison with our own :—

The British and foreign guns compared.

Most of the continental powers at first rifled their old cast-iron guns and strengthened them with exterior hoops of steel or wrought-iron, but more recently they have been supplying themselves either with Armstrong M.L. guns like our own, or with steel B.L. guns manufactured by M. Krupp, of Essen ;* whilst the Americans, who had the most urgent necessity of all for heavy and powerful guns, rifled some hooped cast-iron guns on Parrott's † plan, but they placed greater reliance in S.B. guns made from their excellent cast-iron on Rodman's plan.

Hooped cast-iron guns.

With regard to the hooped cast-iron guns it is well known that the vent is the vulnerable part of a cast-iron gun, and even if the piece were strengthened sufficiently to bear the increased strain, the part adjoining the vent would rapidly wear away, and cause the destruction of the gun.† As for steel its uncertain character renders it a dangerous material for *large* guns, and gunners would do well not to trust it until greater improvements take place in its manufacture.‡

Steel guns.

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* "The enormous scale on which M. Krupp's works are conducted will be understood when it is stated that they cover about 450 acres of ground, about one-fourth of which is under cover, that the number of men employed is 8,000, besides 2,000 more in the coal mines at Essen, at the blast furnaces on the Rhine, and at the iron pits on the Rhine and in Nassau; also, that during the year 1866 the produce of the works was 61,000 tons, by means of 112 smelting reverberatory and cementing furnaces; 195 steam engines, from 2 to 1,000 horse-power; 49 steam hammers, from 1 to 50 tons (the blocks); 110 smiths' forges; 318 lathes; 111 planing machines; 61 cutting and shaping machines.

"The establishment has already delivered 3,500 guns, valued at over 1,050,000*l.*, and it has received orders for the immediate delivery of 2,200 more. Most of the guns made are rifled breech-loaders, from 4-prs. to 300-prs.

"At the Paris Exhibition, 1867, M. Krupp exhibited a 1,000-pr. weighing 50 tons, and a 330-pr. of 12¼ tons, besides smaller guns, all breech-loaders.

"The 1,000-pr. (which he presented to the King of Prussia) has a forged inner tube strengthened with three layers of rings over the powder chamber, and two layers over the muzzle portion; the rings are forged from ingots without welding.

"The manufacture of this gun continued during night and day for 16 months, and the cost of the piece is 15,750*l.* The B.L. arrangement is complicated, and some time would be necessary to go through the different operations in loading." (Report on the artillery at the Paris Exhibition by Lieut.-Colonel C. H. Owen, R.A., in the "Illustrated London News," 31st August 1867.)

It is believed that this great gun of Krupp's has never yet (1871) been fired.

† It is moreover inverting the theoretical order of things to place the stronger material on the outside. "In the attack on Fort Fisher all the Parrott guns in the "fleet burst. By the bursting of five of these guns at the first bombardment 45 "persons were killed and wounded, while only 11 were killed or wounded by projectiles "from the enemy's guns during the attack." (Report on Ordnance, United States Senate, 25th February 1869.)

‡ The following is an extract from a valuable paper entitled "Heavy Rifled Guns," by Major Haig, R.A., F.R.S., in Vol. VI. Proceedings Royal Artillery Institution :—

"Of the danger and uncertainty of steel we have ample evidence, both in this and other countries, and it must be borne in mind that the failure in steel in small guns is an *à fortiori* argument against its use in large guns, and secondly, that these failures have occurred in a comparatively insignificant experience of steel ordnance.

"In June 1860, a puddled-steel 12-pr. made by the Mersey Steel and Iron Works burst at Shoeburyness at the sixth round.

"In June 1861, a 7-inch steel gun by the same makers burst at the sixteenth round; while in November of the same year a 20-pr. Krupp gun burst at the second round.

"In March 1862, a French 30-pr. steel gun burst at Gavres.

"In August 1865, a Krupp 9¾-inch steel gun burst with a moderate charge of powder, a Prussian committee attributing the failure to inferiority of the metal. In Russia, during the same year, a 9½-inch gun of Krupp's steel burst at the sixty-sixth round, and an 8½-inch similar gun burst at the ninety-sixth round.

"In June or July 1866, a 9-inch Krupp gun burst in Russia at the the fifty-sixth round; while in the same year a field gun by the same maker burst at Berlin, killing three cadets.

The large American smooth-bore guns shaped somewhat like a soda water bottle, as suggested by Captain Dahlgren, United States Navy, and cast hollow and cooled from the interior, as proposed by Captain Rodman, are, for cast-iron guns, the best that can be manufactured, and are no doubt from their size formidable pieces, but weight for weight they are inferior to our R.M.L. wrought-iron guns.

The American smooth-bores.

For, supposing the American cast-iron guns are as durable and as little liable to burst as our sinewy guns of wrought-iron, and that their apocryphal charges are actually used, our guns possess the great advantage of being able to *pierce* armour plates with shot, nay even with *shell*, which the American guns could only crush or "rack" with solid shot.

But the United States authorities appear to have at last recognised the superiority of rifled ordnance. In the report of the joint committee on ordnance submitted to the Senate of the United States, 25th February 1869, we find their opinion on the subject thus tersely expressed:—

"The experience of all nations goes to prove that the most effective way of developing ordnance power is by rifled guns. To return to smooth-bores throwing huge spherical masses of iron with low velocities, is to disregard all modern progress in the science of gunnery, and to go back to the arms in use two centuries ago."

"During the Prussian campaign against Austria in 1866, six Prussian steel field guns burst.

"In January 1867, a 7-inch Krupp gun burst at the second round of proof, at Woolwich; and in the same year a 4-pr. burst at Tegel, near Berlin, killing two men.

"In 1868, an 8-inch Krupp gun burst on board a Russian frigate very destructively, killing and wounding in all twelve men.

"In 1869 (January 27th), a similar gun burst in Prussia into twenty pieces.

"Besides these guns large guns constructed of steel, supplied either by Krupp or Petin and Gaudet, have burst violently at Madrid and Turin."

In 1872, an 11-inch Krupp gun burst at the chase and blew about three feet off the muzzle when firing its service charge.

CHAPTER III.

MATERIALS FOR ORDNANCE.

Definition of physical properties.—Malleability.—Brittleness.—Ductility.—Tenacity.—Toughness.— Softness.— Elasticity. — Elastic limit.—Properties of *bronze*.—Unsuited for rifled ordnance.—Properties of *cast-iron*.—Effects of carbon and impurities on iron.—Unsuited for rifled guns.—American and foreign cast-iron.—Properties of *wrought-iron*.—Effect of impurities.—Advantages of fibrous structure.—Suitability for rifled ordnance.—Why not used for the inner barrel of heavy guns.—Testing of iron and appearance of fracture.—Properties of *steel*.—"Soft" and "toughened" steel.—Defects as a material for ordnance.—Advantages for inner tubes.—Relative cost of guns of different materials.—Table of tensile strength.

Considerable light has been thrown upon the composition and character of metallic substances by the progress in chemical analysis, and our present knowledge of the properties of the useful metals is much more intimate than it was a few years ago, though there still remains a great deal to be learned on this subject.

Large and valuable works have been written on the properties and manufacture of iron and steel alone,* but it would be beyond the scope and province of these notes to give more than the leading properties of such metals as are more or less suitable for the manufacture of rifled ordnance, and to the use of which we are limited by considerations of economy.

Under this head may be classed the following, viz.: Bronze (or gun-metal), cast-iron, wrought-iron, and steel. **Suitable metals.**

Before entering, however, into a discussion of the physical properties of these metals which render them more or less suitable for ordnance, it is advisable to have a clear idea of the terms usually employed to express these properties. The following definitions have therefore been borrowed from Dr. Percy's work and other sources. **Definition of terms.**

Malleability is the property of being permanently extended in all directions without rupture by pressure (as in rolling) or by impact (as in hammering). It is opposed to *brittleness* which is the tendency to break more or less readily under compression, either gradual or sudden. **Malleability.** **Brittleness.**

Ductility is the property of permanently extending, or drawing out, by traction, as in wire drawing. **Ductility.**

Tenacity (or tensile strength) is the property of resisting rupture by traction, it is proportionate to the weight which a wire or rod of the metal of a given area is capable of sustaining. **Tenacity.**

Toughness (a term nearly allied to tenacity) is used by practical metallurgists to denote the property of resisting extension or fracture by **Toughness.**

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* For example :—Metallurgy by Dr. Percy, F.R.S. (1864) ; A Practical Treatise on Metallurgy by Messrs. Crookes and Röhrig (1869) ; Truran on the Manufacture of Iron. "Metals" (Messrs. Longmans and Co.'s series) by Professor Bloxam (1870), is a handy book, clearly written, and very much to the point. We recommend it specially to the Artillery Student of Metallurgy.

tearing or bending, thus a piece of copper is said to be more or less tough in proportion to its capability of being bent backwards and forwards without breaking.

Toughness as applied to steel.

Dr. Young (Nat. Phil., i. 142) gives the following explanation of the term toughness as applied to steel. "Steel, whether perfectly hard or of "the softest temper, resists flexure with equal force when the deviations "from the natural state are small, but at a certain point the steel, if soft, "begins to undergo an alteration of form, at another point it breaks if "much hardened, but when the hardness is moderate it is capable of a "much greater curvature without permanent alteration or fracture, and "this quality, which is valuable for the purposes of springs" (and also for gun barrels), "is called toughness, and is opposed to *rigidity* and *brittle-"ness* on the one side, and to *ductility* on the other."

Softness.

A metal is said to be *soft* when it yields easily to compression without breaking, and does not return to its original form on the removal of the compressing force. It is always a comparative term, thus steel is called "soft" or "hard" according to the conditions induced by the special treatment to which it has been subjected.

Elasticity.

Elastic limit.

The *elasticity* of a metal is the amount to which it may be elongated by tension without remaining permanently extended on the removal of the strain, and the *elastic limit* is the weight which can be applied to a bar a square inch in area without permanently altering its form.

These few definitions will enable us to discuss more clearly the properties of the various materials which have been usually employed at different periods for the construction of ordnance. These are, bronze, cast-iron, wrought-iron, and steel.

1st. Bronze.

Properties suited to a gun material.

Deficient in hardness.

1st. *Bronze*, or rather that particular kind called "*gun-metal*," consists of an alloy of about 90 parts of copper to 10 of tin. The properties which render it valuable as a gun material are its toughness and tenacity, the former being so great that it is almost impossible to burst a bronze gun. On the other hand, it is deficient in hardness, being readily indented and abraded by the projectile, and expanded by the force of the explosion, this softness being increased as the material becomes heated from continuous firing; consequently its use in this country for the manufacture of smooth-bore guns was restricted to those intended for field service, in which the weight of charge and shot is comparatively small, and the softness of the material does not consequently so much affect the efficiency of the piece; and even for small rifled guns, such as our 7-prs. for mountain service, it is found to answer very well.

Adopted in 1869 for field guns.

In 1869 bronze was adopted as the material for rifled M.L. field guns, both for our home and Indian services; but so much difficulty has been experienced in getting sound and homogeneous castings, that this metal has been superseded by wrought-iron and steel.* (See Chapter I.)

Reasons for want of uniformity in bronze.

The want of uniformity in large bronze castings is due to the fact that copper and tin do not form one definite alloy in the proportion of ten to one (the theoretical proportion in gun-metal), but will form numbers of alloys varying in the richness of either metal. The specific gravity and temperature of fusion of the two metals being also very different, it follows that they separate more or less from one another while cooling, and thus are formed those tin spots and porous patches which have hitherto led to the failure of this material in rifled guns.

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* *Sterro-metal*, which was tried by the Austrians some years ago, and is an alloy of copper and zinc, with small quantities of iron and tin added, possesses strength, elasticity, and hardness; but it is more brittle and more liable to corrosion than gun-metal.

These defects undoubtedly existed in the S.B. bronze guns, for guns cast at various dates as far back as 1790 have been cut open, and tin spots are found to a greater or less degree in all of them. It is not difficult to account for the more rapid deterioration of a rifled than a S.B. gun from this cause, as the weights of shot and charge are much greater in the former in comparison to the area acted on, and consequently the local heating at the seat of the charge is much more intense. The reduction of windage* also in the rifled gun would tend to increase this local heating, and it must be borne in mind that bronze becomes hot very easily, and that tin melts very soon (442° Fahr.); the result being that the tin spots in the surface of the bore are rapidly eaten away at the seat of the shot. Moreover the grooves in a rifled gun open out many tin spots which would remain unexposed in a smooth-bore, and are found to be very much worn by the studs of the projectile even when zinc is used for the latter.

More rapid deterioration in a rifled than in a S.B. gun.

2nd. *Cast-iron* is the first result of extracting iron from the ore, and it therefore contains many foreign elements, the principal of which are carbon and silicon; the former is derived from the fuel with which it is smelted, but the greater part of the latter comes from the ore. In addition to these two substances, a small quantity of sulphur, phosphorus, and manganese are very commonly found as impurities in cast-iron.

2nd. Cast-iron. Impurities in.

Cast-iron contains from 2 to 5 per cent. by weight of carbon, existing in two states, part being chemically combined with the iron and part mechanically mixed with it.

States of carbon in cast-iron.

In the trade cast-iron is distinguished by numbers from one to eight, the lower numbers being given to those descriptions in which the surface when broken presents a "grey" or "mottled" appearance, and in which the larger part of the carbon is in the state of graphite, that is, uncombined with the iron. The higher numbers represent "white" or "bright" iron, and in these the carbon is almost entirely in the combined state.

It is to the presence of carbon that cast-iron owes its fusibility and hardness, the properties which render it useful for so many purposes, and applicable to the manufacture of guns, but it has the baneful effect of making the material brittle. Grey cast-iron is more fusible and softer than white iron but less brittle, and mottled iron combines the properties of both in a modified degree; hence an iron of this description (about number 4) has always been preferred in this country for the manufacture of ordnance. The presence of silicon, sulphur, or phosphorus also tends to render this material brittle, and the unequal contraction of the various parts of a large casting during the process of cooling, and also the drawing away of the metal from the interior, tend to cause the mass to be unsound, as well as to put some parts of it into a state of undue tension. For these reasons it is evident that cast-iron is not sufficiently strong to resist the strains to which it would be subjected in our modern rifled guns. Moreover, the arguments which bear against the employment of an homogeneous structure (see chapter II., page 22), apply especially to this material on account of its low tensile strength and limit of elasticity (see table, page 36). Undoubtedly several instances have occurred in which cast-iron rifled guns have

Effect of carbon in iron.

Description used for guns.

Effect of other impurities.

Difficulties in casting.

Unfit for rifled guns.

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* The old definition of windage, viz., the difference between the diameter of the bore and of the shot, is not sufficient when we want to describe the opening through which the gas struggles to escape over an *elongated* projectile, as it is evident that the longer the shot the more difficult will it be for the gas to escape, and the greater will be the wear on the upper surface of the bore.

withstood a considerable number of rounds of moderate charges, both of powder and shot, but for every one that has done so many have failed, and the trials have clearly proved that cast-iron guns, such as we have in this country, are quite unable to fire battering charges.

American cast-iron guns.

The American cast-iron is exceptionally good, but their heavy rifled guns (Parott) failed signally in the war with the South, and they have contented themselves for the present with smooth-bores.

Foreign cast-iron.

Swedish and Danish cast-iron, being smelted with charcoal, is very pure, and is superior to that used in this country; the Spanish iron is also very good. But they all have abandoned this material as being quite untrustworthy alone. They have, however (as well as the French), adopted cast-iron guns either hooped or lined with wrought-iron or steel, but, as far as can be judged, only from economical motives.

Merits and demerits as a material for ordnance.

To sum up: the *hardness* of cast-iron is a valuable property, but its *brittleness* renders it unsafe; its tensile strength is not high, and when a gun of this description fails, it bursts violently and deals destruction to everything near it. The only guns, therefore, for which we use it in this country are for second-rate purposes,* and in them the wrought-iron lining is depended upon to give safety to the structure.

3rd. Wrought-iron.

3rd. *Wrought-iron* is theoretically pure iron, but the wrought-iron of commerce is always more or less contaminated with the impurities which exist in cast-iron, though in a minor degree.

Effect of impurities.

It contains from 0·1 to 0·3 per cent. by weight of carbon, and often small quantities of phosphorus and sulphur; the former renders iron brittle when cold ("cold short"), and the latter makes it brittle when hot ("red short"), and consequently the better kinds of bar iron are almost entirely free from them.

Wrought-iron is obtained from cast-iron by burning out the impurities in the process of "puddling" (see page 40), but should the cast-iron be very impure it is found to be impossible to get rid of all the foreign substances; consequently, to get good bar iron it is necessary to use good cast-iron. By rolling or drawing out under a hammer, wrought-iron is given a fibrous structure, the fibres running lengthways in the direction in which the forging has been drawn out. Thus, the fibre runs along a bar of wrought-iron just as the fibre of wood runs along the stem and branches of a tree.

Advantages of fibrous structure of bar iron.

This structural arrangement of the material can be readily demonstrated by subjecting a piece cut off a bar of wrought-iron to the action of acid, when the minute portions of slag and other impurities running through the mass are eaten away, and the fibres of iron being left, present the appearance of a bundle of fine wires. This fibrous quality of bar iron renders it much stronger in one direction than in the other, for—just as in the case of wood—it requires about twice the force to break a piece of wrought-iron across its fibre than it does to tear it asunder along the fibre. In the latter case the fibres need only be separated, not broken, and the cohesion which binds them together is not much greater than that of the crystals which compose good cast-iron. This property is taken advantage of in the Armstrong coil system of constructing ordnance (see page 23).

Welding property.

Wrought-iron may be said to be practically infusible in any ordinary furnace, but it has the property of welding (which cast-iron has not); that is, if two clean surfaces of wrought-iron heated to a white heat (about 3,000°) be brought into contact and pressed together, either by rolling or hammering, they will unite so perfectly that the mass when broken

* Converted S.B. guns.

will part as readily at any other place as at the point of union. Upon this welding property, combined with its malleability, depends the value of wrought-iron in the various arts and manufactures. It is valuable as a gun material on account of its comparatively high *tenacity*, combined with its *malleability* and *ductility*.

Suitability as a gun material.

The elasticity of wrought-iron is not high, but it may be strained to a certain degree without being permanently extended, so that when the strain is removed the material resumes its normal condition, but should the "elastic limit" be exceeded and the iron become permanently extended, then its malleability and ductility come into play, and give a large margin of further extension before the limit of tenacity is reached and the metal breaks. For this reason, even when subjected to comparatively sudden strains, wrought-iron is found to give gradually, and only when the strain is exceedingly violent and dynamical (such as that caused by the bursting in the bore of a shell filled with gun-cotton), has a gun of this material been known to burst explosively. For the above reasons wrought-iron is preferred to steel (in this country) for the exterior portions of rifled guns, though the tensile strength of the latter material when toughened in oil is nearly double that of the former. On the other hand, steel is preferable to wrought-iron for the inner barrel for several important reasons. In the first place, it is found practically impossible to obtain wrought-iron entirely free from slight flaws and defective welds, which, though unimportant in the exterior portions of a gun, are very detrimental in the surface of the bore, more particularly near the powder chamber, where the powder gas acts directly upon them, and rapidly eats them out, thus rendering the gun unserviceable. Again, the comparative softness of wrought-iron causes the bore and grooves to be worn and indented when firing the enormous charges now used, and the very property of extensibility which renders it so valuable for the exterior is to a certain extent a disadvantage in the inner tube, which becomes more and more enlarged with repeated firing, until at last the material is stretched so far that it must yield, and the barrel splits, while the exterior of the gun remains perfectly sound. Now, cast-steel is perfectly clean and free from any defects; it presents a hard surface to the action of the powder gas and the projectile, and its limit of elasticity being far higher than that of wrought-iron, it is not so easily extended. Should it be subjected to too sudden and violent a strain, it may split, but the wrought-iron exterior of the structure then absorbs the blow, and explosive rupture is avoided.

Why wrought-iron is not used for the inner barrel of heavy guns.

In testing the quality of the bar, previous to using it for the manufacture of guns, the amount of drawing out or extension of the specimens previous to rupture is taken into consideration, as well as the weight which the metal will bear without breaking, and the appearance of the broken surface. In good tough wrought-iron the fracture presents an irregular silky appearance, light grey in colour, and shows distinctly the fibrous structure and the extension of the fibres; should the surface be largely crystalline, and the specimen have broken off short without drawing out, it shows that the wrought-iron is deficient in fibre and consequently not well suited to resist the continued strains to which it would be subjected in a heavy gun.

Testing of wrought-iron for guns.

Appearance of fracture.

The "steely" property of the wrought-iron, that is, the amount of carbon it contains is ascertained by an empirical test. The specimen is raised to a red heat and cooled suddenly in water; the effect of this treatment is to increase the tensile strength, but the appearance of the fracture (even in good fibrous iron) often becomes crystalline or granular

Method of ascertaining the "steely" property of wrought-iron.

When condemned on this account.

instead of fibrous, and the wrought-iron has moreover lost to a great degree its property of extensibility, so that it breaks off short. If the increase in the tensile strength when hardened is excessive (more than 2 tons per square inch) and the appearance of the fracture is such as to indicate the presence of a considerable amount of carbon, the iron is rejected, for, as said before, the iron required for gun building must not only have a good tensile strength, but should also possess in a marked degree the properties of extensibility and toughness under sudden strains, so that should the gun be at any time strained beyond its powers of endurance, it may fail gradually, and not suddenly without giving any indication to the gun detachment of its approaching rupture.

4th. **Steel,** Proportion of carbon in it.

4th. *Steel.*—The essential difference between steel, wrought-iron, and cast-iron consists in the proportion of carbon present in each, which proportion is as follows :—

Wrought-iron	0·1 to 0·3	per cent. by weight.
Steel	0·3 to 2·0	" "
Cast-iron	2·0 to 5·0	" "

Wrought-iron is, as said before, as pure iron as we can obtain in large quantities, cast-iron contains a large per-centage of carbon, and steel takes a position intermediate between them in this respect, almost the whole of the carbon which it contains being chemically combined with the iron.

"Soft" steel and "hard" or "toughened" steel.

Steel in its natural state after casting and forging is nearly as soft and inelastic as malleable iron, but it may be hardened by being heated and plunged into cold water. The effect of this process is not only to harden the material but also to render it exceedingly brittle (on account of the unequal state of tension into which the particles have been forced by the very sudden cooling), and consequently quite unfitted to resist any sudden or dynamical strains. In order to obtain the useful properties of hardness and increased tensile strength, and at the same time as far as possible to avoid the glass-like defect of brittleness, oil is sometimes used instead of water for hardening steel. Now oil is, as a liquid, a very bad conductor of heat, and it does not boil under 600° F. Consequently when hot steel is plunged into it, the mass parts with its heat much more slowly than when water is used, and is *toughened* as well as hardened. The temperature to which the material is heated also affects the result. Mr. Kirkaldy in "Experiments on wrought-iron and steel" gives the following illustration of the effect of different modes of cooling upon the physical properties of steel* :—

Nature of Specimen.	Tensile Strength (tons per square inch).	Elongation per cent.	Character of Fracture.
1. Highly heated and cooled *in water*	30	0	Entirely granular.
2. Highly heated and *cooled slowly*	36½	22	Entirely fibrous.
3. Moderately heated and cooled *in oil*	53	14½	⅓rd granular. ⅔rd fibrous.
4. Highly heated and cooled *in oil*	58	2½	Almost entirely granular.

* "Text-Books of Science : Metals," by C. L. Bloxam, &c. &c.

The above results show at a glance the advantage to be obtained by the judicious treatment of steel, and when we come to the manufacture of this material for the inner barrels of guns, it will be seen that every advantage is taken of the knowledge gained by such experiments as the above. However, even after the best has been done for it, some of the defects of steel as a material for ordnance, though modified, remain, and therefore (notwithstanding its high tensile strength under statical strains) we do not use it for any portion of our large guns, except the inner barrel. These defects may be stated to be brittleness, uncertainty, and deficiency in extensibility when strained beyond its elastic limits.

Defects of steel as a material for ordnance.

The brittleness of steel when subjected to sudden strains and its liability to fly into pieces without warning has been referred to before.

Brittleness.

Its uncertainty is such that no two specimens, even out of the same ingot, are found to behave exactly alike when tested, or to possess the same structure and other physical properties. It is therefore found absolutely necessary to test each individual ingot previous to putting it into a gun.

Uncertainty.

The great ductility of wrought-iron between its elastic limits and its breaking point render it far safer than steel for the exterior portions of guns, and more than compensates for its lower limit of elasticity and tensile strength.

Deficiency in extensibility.

As regards want of uniformity and trustworthiness, Mr. Anderson remarks,*—" Cast-steel is the most expensive of all cannon-metals, yet, " from its soundness in the bore, if it could be made as trustworthy as " wrought-iron, and if, at the same time, it could be depended upon for " the certain possession of toughness, it would be perfection notwith- " standing the cost; but the uncertainty of manufacture which now " exists must first be completely removed before it can be compared " with wrought-iron as an instrument for men to fire and stand along- " side of with perfect assurance of safety; and, as wrought-iron is so " reliable and the cost moderate, there is no particular want felt for " steel to constitute the entire body of the gun."

Mr. Anderson on steel.

To sum up: steel from its hardness, high tensile strength, and freedom from flaws and defects, is better suited than wrought-iron for the inner barrel of a gun, while its brittleness and uncertainty render it unsuitable for the exterior portions. The construction adopted in the service is therefore founded on correct principles, as far as the materials and their arrangement are concerned, and the correctness of the principles has been proved by twelve years experience, during which period thousands of guns have been manufactured and issued, and, in no one instance, has a gun burst explosively on service, nor has a single life been sacrificed. This is more than can be said of those services which have been armed with cast-iron or steel ordnance.†

* Journal of the United Service Institution, August 1862.

† The relative cost of guns made of the several materials we have discussed may be stated in round numbers to be as follows:—

	£	
Cast-iron guns - - - - - - - -	21	per ton.
Armstrong (original construction), wrought-iron, with steel tube	100	"
Ditto ditto (Fraser construction) - - - -	65	"
Steel, on Krupp's or Whitworth's plan - - - -	170	"
Gun-metal - - - - - - - -	190	"

TABLE showing the LIMIT of ELASTICITY and TENSILE STRENGTH of Average Specimens of the Metals used in the R.G.F.

Materials.	Tons per Square Inch at		Elongation per Inch at Breaking.
	Yielding.	Breaking.	
Bronze -	6·8	14·9	0·29″
Cast-iron from	about 4*	9·0	*
Cast-iron to		14·0	*
Wrought-iron along its fibre	11·0	22·0	0·3 ″
Steel soft	13·0	31·0	0·21″
Steel tempered in oil	31·0	47·0	0·11″

Roughly speaking, wrought-iron is twice as hard as bronze, cast-iron is twice as hard as wrought-iron, and hardened steel is twice as hard as cast-iron.

CHAPTER IV.

PRINCIPAL OPERATIONS IN THE MANUFACTURE OF RIFLED ORDNANCE.

Machinery.—Definition of terms used.—Conversion of circular into reciprocating motion, &c.—Reversal of motion in rifling machines.—Steam hammers.—Table showing power of hammers.—Manufacture of solid forgings.—Bar iron.—Shape of bars.—Welding bars. — Coiling. — Double and triple coils. — Welding coils.—Uniting coils to form a tube.—Manufacture and testing of steel ingots.—Centring.—Turning.—Boring.—Shrinking.—Broaching.—Lapping.—Rifling.—Calculation of tangent bars for rifling. — Drilling. — Screw-cutting. — Slotting and planing. — Viewing and gauging.

Machinery.†

In the Royal Gun Factories steam power is employed for driving the whole of the machinery, and also for working the heavy hammers, while hydraulic power is used in some of the heavy cranes and testing machines. Before proceeding to detail the various more important operations it is advisable to explain briefly some of the terms used in mechanics, in order to facilitate the description of the different machines used in the Department.

Method of communicating motion from the

Steam engines are employed, as in most factories, to give rotation to long pieces of "*shafting*" or rods of iron which run the whole length

* The specimens of cast-iron tested in the R.G.F. are too short to enable the yielding point and elongation to be accurately determined.

† For a fuller description of machinery *see* "The elements of Mechanism," by T. M. Goodeve, M.A. The details in this and the following chapters are intended more especially for the instruction of Artillery Classes in the R.G.F.

of each shop, and carry a number of "*pulleys*" or wheels having a broad circumference or rim. Motion is transferred by means of "*belts*" or "*bands*" of leather from these to similar pulleys attached to each machine, this being the method usually employed for communicating motion from one axle to another at a distance from it. When axles are near one another "*tooth-wheels*" are used to transmit the power; these wheels being of different forms and sizes according to the relative positions of the axles and the work which the machine is required to perform. When the axles are parallel the ordinary "*spur-wheels*" are used, that is, wheels in which the teeth project radially from the circumference. If not parallel, wheels having the teeth formed on the surface of a cone instead of on the circumference of a circle, must be employed; these are called "*bevil-wheels.*" engine to the machines. "Belts" or "bands." "Tooth-wheels." "Spur-wheels." "Bevil-wheels."

"*Mitre-wheels*" are bevil-wheels of equal size whose axes are at right angles to one another, and are much used for changing the direction of motion. "Mitre-wheels."

A "*pinion*" is a spur-wheel with a small number of teeth gearing into a larger wheel or into a rack. A "*rack*" is the name given to a straight piece having teeth projecting from its surface. "Rack and pinion."

A "*worm-wheel*" is a spur-wheel with oblique teeth shaped so as to gear with the thread of a screw, and the combination of the two is one method of obtaining increased power by the sacrifice of velocity. This arrangement is in general use in steam cranes, for should any part of the engine get disabled the screw becoming fixed prevents the lift running down. Another way of increasing power at the loss of velocity is also effected by using tooth wheels of different sizes; thus, if a wheel one foot in diameter with 10 teeth be made to drive another five feet in diameter and having 50 teeth, the latter will revolve only once while the former turns five times, but the force required to stop the large wheel will be five times that which works the small one, not taking friction into account. "*Cone-pulleys*" can also be used for varying the speed of machines. "Worm-wheel." Methods of increasing power. "Cone-pulleys."

Wheels of different sizes are also used to vary the rate of revolution of the work without reference to the power. For instance, in the screw-cutting lathe there is only one screw used as a copy, but a "*thread*" of any required "*pitch*" can be cut by introducing a series of "*change-wheels*" so as to alter the ratio of the revolution of the work to that of the copy. "Change-wheels."

A "*screw-thread*" is a projecting rim running spirally round the exterior or interior of a cylindrical surface; the former is called a "*male*" thread, and the latter a "*female*" thread, and the rim of each is shaped so as to correspond with the other. The "*pitch*" of a screw is the distance between corresponding edges of two adjacent threads measured parallel to the axis of the screw, and is the distance the screw travels when completing one revolution on its axis. In practice the pitch of screw bolts is usually estimated by the number of threads in an inch of length, thus, the screw of the new pattern copper vent bush is called "seven threads to the inch." "Screw-thread." "Pitch of a screw."

Screws are generally *right-handed*, that is, the screw progresses when turned in the same direction as the hands of a watch. *Left-handed* screws are, however, sometimes used for special purposes, as in the instrument for taking impressions of the bores of guns. Generally "right-handed."

A "*double-threaded*" screw is one in which two parallel threads starting from opposite sides of the cylinder are wound round it side by side. The object is to increase the bearing surface of the thread without reducing the pitch, that is, the rate of progression. Thus, in a single threaded screw of one inch pitch the screw travels one inch for each "Double-thread."

turn, but if an intermediate thread be wound round the bolt the bearing surface will be as great as that of a screw whose pitch is only 0·5 inch, but the travel of the bolt will still be one inch. This kind of thread is therefore used in cases where considerable resistance to shearing is required, while the saving of time is also an object as in the breech-screw of the 7-inch B.L. gun.

Conversion of circular motion into reciprocating, and vice versâ.

Now in order that the various machines may be capable of performing the work required of them, the rotatory motion derived from the steam engine must be changed into rectilinear and other motion, and nearly the whole of the combinations of machinery may be said to consist in different methods of converting *circular* motion into *reciprocating* motion, and vice versâ.

"Cams."

The conversion of circular into reciprocating motion is most commonly effected by means of "*cams*" (the ordinary eccentric being only a particular form of cam), which name is given to a curved plate fixed to, or a groove cut in, a revolving spindle, which plate or groove communicate motion to another piece by the action of their curved edges; by varying the form of the plate or groove any required motion can be obtained.

"Crank."

"Pawl and ratchet."

Rectilinear motion is converted into circular by the "*crank*," as in a steam engine, or by means of a pawl and ratchet-wheel, the pawl being carried on a jointed arm worked by a cam; the former gives continuous motion, while the latter gives intermittent motion such as is required in the "*feed*" of slotting and other similar machines.

Reversal of motion in boring and rifling machines.

The following is the method employed for reversing the motion of the boring or rifling machines. The saddle carrying the boring (or rifling) bar works on a screw running the whole length of the machine. On the end of this screw, away from the gun, is fixed a bevil-wheel, into which two other similar wheels gear, the axis of the two latter being concordant and at right angles to that of the screw. One wheel is attached to a pulley by a hollow spindle, through which a smaller spindle passes, connecting the other wheel to a second pulley, so that each is capable of turning independently of the other. Between these two pulleys is a third, riding loose upon the spindles, and called an "*idle-pulley*"; the workman by shifting the band to this idle-pulley, can stop the machine without interfering with the rest of the shop, and by shifting the band to one or other of the "*fast-pulleys*" he can set the machine in motion in either direction, as the direction in which the screw will turn, and consequently the saddle travel, depends upon which bevil-wheel the power is passing through. When once set in motion the machine is self-acting. So soon as the saddle reaches one extremity of the bed a projection on it comes in contact with a stop fixed on a rod running along one side of the machine. This rod acts on the band through a series of bent or "*bell-crank*" levers, and shifts it from the one driving pulley to the other, passing over the idle-pulley. Thus the power is transferred to the other bevil-wheel, and the motion of the saddle reversed. On reaching the other end of the bed the projection from the saddle acts upon the rod in the opposite direction, the band is shifted back, and the motion again reversed.

"Idle-pulley."

There are other methods of reversal employed in the machines in the Department, for instance, by passing the power alternately through a different number of spur-wheels, but the one described is that most used, and is at the same time remarkable for its ingenuity and simplicity.

Nasmyth's steam hammers.

Steam Hammers.—The most powerful hammers employed in the Royal Gun Factories are Nasmyth's double acting steam hammers, that is, hammers in which the steam power is used not only in raising the block but also in driving it down upon the forging. In these

the steam cylinder is fixed, and the falling weight is attached to the piston, but smaller ones are used constructed after Condie's patent, in which the piston is fixed and the cylinder moves, thus forming part of the falling weight. The piston is a double pipe through which the steam passes into the cylinder; when steam enters through one pipe it lifts the cylinder, and when through the other it drives it down on to the forging.

Condie's.

It is impossible to say absolutely what blow per square inch any particular hammer can give, as it varies with the height and size of the mass being forged, the pressure of the steam in the boiler, &c. &c.

Power of hammers used in the R.G.F.

The following table gives however a comparative statement of the equivalent in *foot-tons* * for each hammer, supposing the block to fall the full stroke of the cylinder and the steam pressure to be about 50 lbs. on the square inch.

TABLE showing the POWER of STEAM HAMMERS in the Royal Gun Factories.

Nominal Weight of Block.	Actual Weight of Block.	Diameter of Cylinder.	Length of Stroke.	Pressure of Steam on Piston.	Blow on Anvil.
	Tons.	Inches.	Feet.	Tons.	Foot-tons
Nasmyth's, 30 tons - -	34	55	10·5	53	913
" 12 " - -	16	38·25	7·66	25	314
" 10 " - -	14	37·625	8·41	25	328
" 7 " - -	8	29·125	6·33	15	146
Morrison's, 4 " - -	4	26·5	4·75	12	76
Condie's, 3½ " - -	3½	23·25	4·83	9·5	63

Having thus briefly noticed some of the principal features in the machines used in the Gun Factories, we shall now describe the various manufacturing operations.

Manufacture of Solid Forgings.

Solid forgings are used in the Royal Gun Factories for breech-pieces, trunnion-rings, cascables, &c. It is probable that few or none of the first named will be made in future, but as all the R.B.L. guns and many of the R.M.L. guns have a forged breech-piece, its manufacture must not be wholly omitted. Every large solid forging is made in the same way, namely, of slabs of iron successively welded together on the end of a porter bar, which acts both as lever and tongs in manipulating the work. The slabs are made from scrap iron, which is of two kinds, one being scrap, properly so called, and consisting of all kinds of old wrought-iron articles,—bolts, nuts, keys, screws, horse-shoes, musket-barrels, hooks, crooks, &c., &c.,—which are purchased by contract and which must be "drummed" to clean off the rust before they are fit for use. The other kind of scrap is the shavings obtained in the process of turning and boring the various parts of the guns. The former is the most tenacious and the latter the most uniform in structure.

Two kinds of scrap iron.

The furnace used in this, and indeed in all the operations in the Royal Gun Factories in which it is necessary to raise iron to a white or welding heat, is a reverberatory one, that is, a furnace in which a bridge of fire-brick placed between the grate and the hearth prevents the contact of the coal and the iron which would be detrimental to the latter, while the

The reverberatory furnace.

* A *foot-ton* is the blow struck by a ton falling through one foot.

powerful draught generated by a tall chimney at the other side of the hearth induces the flames to play upon the metal with great intensity. The chimney is provided with a damper or lid, raised and lowered by a chain attached to a lever at the top so that the draught may be regulated to a nicety, and stopped altogether when the hearth is temporarily empty.

Blooms of scrap iron. A charge of scrap iron is put into the furnace, and when heated sufficiently to adhere together is brought out in balls weighing about 1 cwt. and "shingled," that is, placed under a steam hammer, by means of which any liquid slag is squeezed out, and the ball formed into an oblong block called a "bloom." The bloom is again heated and hammered into a flat cake, and several of these cakes are "piled" together, heated, and formed into a slab.

Breech-pieces. To make a breech-piece, for a 40-pr. for example, two slabs are placed on the flattened end of a porter bar, put into a furnace, heated, and welded on. Two other slabs are then welded in a similar manner to the under surface. Two cross or binding slabs are next welded on in succession to the sides of the first four slabs, and thus a rough cubical block is formed. This block is then heated and "drawn" or hammered out to a cylinder, which is about twice as long as it is thick. The cylinder having been cut off from the end of the bar is bored and turned into a breech-piece of the required shape and size.

Trunnion-rings. A trunnion-ring is made in like manner, but the porter bar is in continuation of one of the trunnions, and no binding slabs are necessary. The block is gradually formed into a ring by means of, first, a small iron wedge which is driven through the centre, and punches an oval hole, and secondly, by a series of taper mandrils increasing in size which makes the hole sufficiently large and round. The trunnion-ring has to be heated for each punching, and the occasion is used to hammer the trunnions roughly into shape. The fibre of the iron runs round the ring which is the most suitable direction. Trunnion-rings are made chiefly of shaving scrap.

The Manufacture of Bar Iron.

Until the commencement of 1868 the bars used for coiling were supplied by contractors, but puddling furnaces and a rolling mill were then erected in the Royal Gun Factories, and all the bar iron required is manufactured on the spot from obsolete cast-iron articles such as carronades, gun carriages, &c., as well as from the scrap iron before mentioned.

The cast-iron must of course be puddled for the purpose of purifying it from its excessive carbon, phosphorus, sulphur, silicon, &c.

Puddling. The metal having been broken up under a steam hammer into fragments of convenient size, the process of puddling is effected in a peculiar reverberatory furnace, of which the usual charge is about 5 cwt. 14 lbs., to this is added about 1 cwt. of iron scales (black oxide of iron, $Fe_3 O_4$) to assist in oxidising the impurities and their consequent departure from the metal. When, therefore, the mass is fuzed and well stirred together the carbon is converted into carbonic oxide with the usual ebulition, and escapes in blue flames from the surface of the metal, whilst the remainder of the released impurities pass off, principally in the slag. The source of its fusibility (carbon) having taken its departure the iron becomes pasty; the puddler then divides the mass with his paddle into three balls, each weighing about 184 lbs. When a ball is sufficiently worked up, it is quickly removed to a steam hammer, where the large quantity of liquid slag adhering to it is squeezed out, and it is formed into a bloom,

Two blooms are welded together, and while still hot passed through the first four of the adjacent rolls, and made into a flat bar. Puddled iron is hard and brittle, and does very well for railways, but is not by itself suitable for guns unless re-worked in order to give it fibre; similar flat bars are therefore made from scrap iron blooms composed of bolts, nuts, &c. Blooms of puddled iron.

These flat bars weigh about 2 cwt. each, and a sufficient number of them are piled or fagotted together to form a bar of the size it is intended to roll. This pile, composed partly of puddled iron and partly of scrap, the former being always placed on the outside on account of their more even surface, is raised to a white heat and rolled into a long bar about 24 feet long, and varying in section from 2½ to 7 inches, according to the purpose for which it is intended. Should the bar be required for the inner jacket of a gun, or for the tube of a 64-pr. gun and guns converted on Major Palliser's system, it is cut into lengths, again fagotted, raised to a welding heat, and passed between the rollers; in ordinary cases one rolling is sufficient. Piling. Rolling.

A bar is always designated by the depth of its section. The section is slightly trapezoidal in order that when the hot bar is wound round the mandril, narrow side inwards, the spreading of the inside and the narrowing of the outside, natural to such a process, may be neutralized and no space left between the folds of the coils. Shape of bar.

Samples of each week's work are tested for tensile strength and elasticity, and usually with most favourable results, the stretching weight being about 12 tons, and the breaking weight 23 tons. Test.

To weld two bars together the ends must be scarfed down and placed from opposite sides in a furnace, from which when they arrive at a white heat, they are withdrawn and welded under an adjacent steam hammer, sand having been thrown on the hot bars (as is indeed customary in the case of all forgings) in order to clean the surface and prevent scale forming, by converting the superficial oxide into a liquid silicate which will flow off of its own accord or be squeezed out by the hammer. Another bar is welded on in a similar way, and so on, until a sufficient length is obtained for the required coil. Welding. Why sand is used.

Coiling.

The bar to be coiled having the ends flattened down, is placed on trestle rollers in front of a long reverberatory furnace with a chimney at the far end and grates along its sides.* A chain being hooked into an eye or hole in the far end, the bar is drawn by machinery into the furnace. When the bar arrives at a bright red heat, the end near the door is drawn out by means of the same eye, and attached to a pin, this end being cooled with water to prevent it tearing away with the weight of the bar. This pin is connected with a slightly taper iron roller or mandril fixed across and in front of the door of the furnace. The mandril tapers in order to facilitate the removal of the finished coil. The apparatus is then put into gear, and the mandril revolves, winding the bar round it. During the process scales form between the folds, but their effect is almost entirely nullified by subsequent heating and forging, sand being used to assist in liquifying the oxide, as stated above. When the coil is formed, the fixed extremity is hammered off the pin and water is poured on that end to cool it, in Furnace. Winding bar.

* The longest bar coiled in the Royal Gun Factories is 270 feet in length. The furnace is only 190 feet long, but in those rare cases the bar projects the extra length outside, and is drawn in according as the other end is coiled.

order that the folds there may not be opened out in the taking off of the coil. If the coil be large, a short iron bar is placed with one end resting on the ground, and the other end against the extremity which has been removed from the pin. The mandril is then turned in the same direction as that in which it revolved when the coil was being formed, and the coil, being prevented from revolving by the iron prop, is loosened and slips down towards the narrow end of the mandril. The mandril is then lifted by a crane and the coil drops off. Small coils are hammered off, no water being used in this case.

Detaching coil from mandril.

Double coil.

If a double or triple coil is required, a round bar is fixed by bearings at each end through the newly made coil when cold, and placed on the supports hitherto occupied by the mandril; the second bar is then wound round the first coil in the same way that the first bar was wound round the mandril, but in the reverse direction to break joints. A triple coil is formed by immediately winding a third bar around the second coil in the opposite direction. Thus the first coil acts as a mandril to the second, and the second to the third, whilst the bar upon which all three revolve is easily extracted when the triple coil is completed. The inner coils project at the ends, a little beyond the outer ones in order that a close weld may be obtained at the interior of the cylinder.

Triple coil.

Object of welding coils.

The object of welding a coil is to unite the folds so that it may withstand the longitudinal strain. The operation is generally the same for all kinds and sizes of coils, single, double, and triple. When the coil is intended for an inner barrel, as in the case of B.L. guns or cast-iron guns converted on Palliser's plan, the process must be very carefully performed; for if from the badness of the iron or from dirt or grit between the folds, or from insufficient heating or from undue hammering the welding becomes imperfect, the barrel will of course be unsound, and the powder gas will eat its way into the defective parts. Indeed the difficulty of obtaining a perfect coiled tube was at one time so great that two out of every three barrels were rejected, but excellent iron having since been procured for the purpose, the per-centage of defective tubes has been greatly reduced. Steel is however preferred for the inner barrels of the heavy guns.

Great care necessary with inner barrel coil.

The coil is placed upright in a reverberatory furnace, for were it placed on its side, it should be turned over in order to be equally heated all through, and moreover drippings from the fire-brick which line the furnace would probably fall from the roof in between the folds. If intended for an inner barrel, two furnaces are used; one is at a low temperature (termed a "blue light"), and when the coil arrives at a red heat it is brought out and transferred to the other, where it is brought to a welding heat. This is found to be more economical than placing the cold coil at once into a very hot furnace, and also prevents any injury to the iron which would result from so doing. In all cases of welding it is necessary to "strike while the iron is hot," and that the surface to be joined should be perfectly clean, the white hot coil is therefore transferred from the furnace to the steam hammer as quickly as possible, and sand is thrown upon it for the reason before assigned. The coil is first placed vertically under the hammer, and receives a few smart blows to weld the folds, it is then thrown on its side and being gradually turned, is hammered (or patted) all round to straighten it. It is then raised vertical again, and a punch or mandril—rather over half the length, and a little larger than the interior diameter of the coil—is hammered down its own length, the coil is next placed on its side and hammered round, that half of its length thus being made very compact, and large enough to let the mandril fall out. After this the coil

Process of welding.

is again raised vertical and the mandril is forced in the opposite end and the process repeated.

The mandrils are of coiled iron and very hard.

The reason a long mandril is not forced through the whole length of the coil is that it would tend to separate the folds.

The coil is replaced in the furnace for the second heating, and much the same process is followed to render the ring more consolidated as well as more shapely; and if intended for an inner barrel, a fine mandril is used to make the interior more perfect. If the coil is to be "faced," a flexible steel bar is used under the hammer to flatten the ends and prevent their being bell-mouthed.

Why water is used. Before the coil is removed from the hammer, water is thrown over it, which, forming into steam blows off the black scales and shreds when the work is good, but a black spot is left by the water if there is a bad part.

Loss in length. Coils lose in welding from one-tenth to one-third of their length according as they are thin or thick.

After welding the cylinder is inspected by the gaugers as to size, shape, and soundness, and unless found satisfactory in all respects is subjected to another heat.

Uniting two or more coils to form a tube.

Purposes for which coils are united. When a coiled inner barrel is required, several coils must be welded together; and the *B* tube or chase of heavy guns is composed of two united coils.

Preparation. In both cases the coils must be faced (turned smooth at the ends) and reciprocally recessed; that is, a projection (spigot) is formed at one end of a coil, while a recess (faucet) is bored in the corresponding end of another coil. The height of the shoulder is a little greater than the depth of the recess in order that a close joint may be obtained on the interior The recess is then expanded by heat and shrunk over the projection, so that the two coils are stuck sufficiently together to admit of their being put into the furnace for welding.

An inner barrel how formed. If intended for an inner barrel the tube is put crossways through a furnace so constructed that intense heat acts on the joint while the remote ends project outside. When the joint arrives at a welding heat a stout iron bar is passed right through the tube, this bar is keyed up at one end, and by means of a screw-nut worked by a long lever at the other end, the two coils are welded or pressed together. The pressure slightly bulges the metal at the junction so it must be straightened under a steam hammer. Another coil is then added on in a similar manner, and so on till the tube is of the required length.

B tube. Should the uniting furnaces be required for inner barrels, the two coils for a *B* tube—being short and strong—are, when shrunk together, heated in an ordinary furnace and welded gently together under a steam hammer.

Manufacture and testing of steel ingots.

Steel ingots for the inner barrel of guns are supplied to the Royal Gun Factories by the contractors in the form of solid cylinders cast and afterwards forged under a heavy hammer. Casting is necesssary, not only for the purpose of obtaining a sufficiently large block of steel, but also for making the block homogeneous and uniform in structure. Forging or drawing out the cast block imparts to it the desirable properties of great solidity and density.

Casting. The cylinder is manufactured thus:—A large quantity of steel having been broken up, the pieces whose fine fracture indicates a

mild nature, are placed with a little flux in a number of plumbago crucibles containing about 45 lbs. each. The air furnaces for heating these crucibles are on a level with the floor of the foundry, and are ranged round the sides of the building, the mould being in a pit in the centre. The furnace fires are fed from galleries running beneath the floor.

The metal is melted in about three hours, when the crucibles are lifted, one by one, from the furnaces by means of tongs, and wheeled quickly to the mould. An ingot for a 9-inch gun, weighs about 65 cwt., so 162 crucibles are required, and a large number of men are employed in rolling up and pouring in the metal. They are obliged to keep up a continuous flow of molten metal, else the casting would not be homogeneous, the operation lasting about 20 minutes.

The mould is of cast-iron and octagonal in shape, being smeared inside with some non-conducting substance, generally a mixture of black lead and oil.

That for the 9-inch ingot is 5 feet long and 2 feet thick. After casting the steel is covered with ashes or other non-conducting substances, and allowed to cool very gradually; when cold a portion is cut off the top, and the lower end being the denser, is marked for the breech.

Forging. The block thus formed is drawn out by a series of heatings and hammerings which occupy several days, to a cylinder sufficiently long for an inner barrel, in which state it is sent to the Royal Gun Factories, where it is subjected to the following tests and treatment.

Testing. A slice is cut off from the breech end and divided into pieces for testing. Some of these are flat bars, 4 inches long and $\frac{3}{4}$ by $\frac{3}{8}$ in section, and others are of the shape usually tested in the machine for tensile strength and elasticity, viz., small cylinders 2″ long between breaking parts, and 0·533 in diameter, having shoulders at each end by which they are fixed in the machine.

Bending test. Three of the former are marked respectively *S*, *L*, and *H*. One end of the *S* or soft (*i.e.*, untempered) piece is gripped in a vice, whilst the other end is hammered down towards it, to ascertain that the steel, by bearing this bending without cracking, is naturally of the mild quality required. The *L* and *H* pieces are raised to a low red, and high heat respectively, immersed in oil, and, when cold, treated in a similar manner. The heat is judged by an experienced workman from the colour of the specimen.

Whichever of these pieces bears the hammering best, determines the heat at which the whole tube is to be toughened (see page 105). Should neither piece answer, others at intermediate temperatures are tried, and if all fail, the block is returned to the contractors; but some specimen having succeeded, as is generally the case, two of the remaining pieces—one in its soft state, and the other toughened at the ascertained temperature—are tested for tensile strength and elasticity. The soft material should begin to stretch permanently at 13 tons per square inch, and break at 31 tons. The toughened piece should begin to stretch at 31 tons, and break about 50. The permanent elongation is also taken, but it is not considered necessary to lay down any limits in this respect.*

* It may seem remarkable that the colour at which a razor, a chisel, or a watch-spring must be tempered is definitely fixed, and yet that the heat for toughening a gun-barrel should vary in shade from a blood red to a bright cerise. Now, did the temperature depend alone on the amount of carbon in the steel, it would appear best to toughen every barrel at a bright heat, for the less carbonized, or in other words the milder the steel, the higher is the temperature at which it toughens most satisfactorily; but it is a fact that the denser the steel is—*i.e.*, the more it is hammered in the process of drawing out—the less heat does it require for successful toughening; hence, each individual barrel must be tested. Doubtless a little more experience will teach us the exact mildness and density suitable for a steel barrel, and the proper temperature to which it should be raised, before being immersed in the oil.

The machine used for testing the tensile strength consists of two levers, one acting on the other in such a manner that any weight applied to the first exerts a strain 200 times as great on the test specimen. Test of tensile strength.

Ingots which pass all the foregoing tests are accepted and are toughened in oil at the approved temperature previous to being put into the gun.

Centring.

Previous to the first turning of any article, the axis must be found so as to centre it truly in the lathe. This is simply done in a solid cylinder by finding centres at each end with a pair of compasses; but in the case of a tube, bars of soft iron must be fixed across each end in order that the axis may be actually ascertained; the article being fixed accordingly in the lathe is turned truly cylindrical. Centring.

Large coils and jackets are centred as follows:—an iron spindle is passed through the interior and supported at either end, any flaws or defects on the interior are searched, and the spindle adjusted by means of a bar gauge so that the interior may be smooth and "clean" when bored to the proper diameter, the axis of the spindle being the axis of the bore; the ends of the mass are then whitened with chalk and a circle marked (with the spindle as centre) on each end by a scriber showing the amount to be bored out. The block upon which the cylinder is supported when in the turning lathe is adjusted to these circles, so that the exterior may be turned concentric to the interior.

Turning.

Turning means cutting off the exterior surface all round. The machine generally used is a turning lathe on the ordinary principle, the work revolving as the cutter, fixed to a sliding saddle, moves along the side. In most machines two cutters work simultaneously, and rough or fine turning can be done as required. Turnings generally assume the shape of long ringlets and are again worked up into blooms. The ordinary lathe.

The size and power of the machines vary with the nature of the work. Those for turning the large breech coils of our heavy guns weigh each with foundations about 100 tons, and can turn off 7 inches in diameter in one cut. By arrangement whereby the motion can be sent into the machine through additional tooth-wheels of different diameters the speed can be greatly reduced and the power consequently increased.

Boring.

The term boring is applied either to the process of reaming out the inside of a tube, or boring one out from a solid cylinder.

Rough and fine boring of an inner barrel, as well as broaching and forming the chamber, are all effected in the same horizontal machines, the difference being in the shape of the boring-head and cutters. In this machine the barrel revolves, while the boring-head, guided by a supporting frame at the muzzle, simply progresses down the bore, being fed to its work by a long screw which passes through a nut in the sliding saddle to which the bar is fixed. The same effect would be produced did the tube move forward and the cutters revolve, but the shavings would obstruct the action by congregating at the bottom. The boring-head used for rough cutting is what is called from its shape, "a half-round bit," it has one pointed cutter set angularly and three steel "burnishers," or projections, to keep it steady The same machine for rough and fine boring of an inner barrel. Rough boring-head.

in the bore. This tool cuts away the metal in front of it and the same kind of head is used for cutting from the solid. In boring out a steel barrel for a 9-inch gun, 8¾ inches in diameter are taken out at each cut in segmental chips about ⅛-inch thick, and the operation takes 56 working hours, or about a week.

Fine boring-head.

Fine boring is performed with a round head having long cutters let in lengthways, and five lignum vitæ wood burnishers. The object of having the latter of wood, is that they may be set out further than the cutters, and so be cut to the same diameter as the tube on entering it, as well as being expanded up to the full size of the bore by the water,* which is invariably projected down the bore; moreover were the burnishers of steel they might indent the bore.

Machine for short and light tubes.

Short and light tubes, such as *B* tubes of R.M.L. guns, are bored in a horizontal machine, but on the opposite principle to that for inner barrels. The tube is fixed in a saddle capable of sliding along the frame of the machine, and the boring bar, through which are placed two adjoining and opposite cutters, is then passed through it and fixed at each end of the machine. The bar revolves while the saddle moves forward, and thus the boring is effected. This mode requires the bar to measure between the supports twice the length of the work to be bored, and the cutter to be in the middle of the bar; it is therefore unfit for long objects.

Large masses.

Large masses, such as the breech coil for a heavy gun, are bored in machines, somewhat similar to the preceding, but the work is stationary and the tool goes through a double motion of rotation and progression, the latter being given by means of a screw which passes lengthways through the side of the revolving bar, and is connected with the boring-head which in the shape of a ring slides along the bar; the screw is turned by a sun and planet wheel at the extremity of the bar.

The difference between the rough and fine cutters is (as generally the case) that the former are deep and narrow, and the latter shallow and broad.

B.L. barrels.

The inner barrels of B.L. guns used to be fine or finished bored in a vertical machine, but this is not used with a solid ended steel barrel, as the cuttings are liable to get in between the boring-head and the bore, and thus injure its surface.

Trunnion-rings.

Trunnion-rings are both rough and fine bored in vertical machines, the work being stationary whilst the boring bar revolves and moves downwards.

Centring.

Large masses are centred by the exterior which has been previously turned.

Coiled wrought-iron tubes for the barrels of 64-prs. and converted guns are bored before being turned, for if on examination of the bore a defect is detected which would condemn it, the labour and expense of turning is saved.

Centring of a tube.

Previous to the first boring of any tube the axis must be found as before described, and a bearing turned off at each end, by means of which it may be truly centred in the boring machine.

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* More correctly soap and water. This mixture acts like oil in diminishing the friction on the tool, and it is much cleaner and cheaper; moreover the water keeps the tool cold and hard, and the soap prevents the formation of rust. It is always used in turning, boring, slotting, &c., iron, steel, and bronze.

Shrinking.

Shrinking is employed not only as an easy and efficient mode of binding the successive coils of a built-up gun firmly together, but also for regulating as far as possible the tension on the several layers, so that each and all may contribute fairly to the strength of the gun.

Double object of shrinking.

When two coils or tubes are to be shrunk together the interior of the outside one, having been fine bored to that degree of smoothness which is necessary for close contact and mutual support, is gauged to $\frac{1}{1000}$th of an inch every 12 inches of its length as well as at every shoulder it may have. To these measurements the shrinkage is added, and a plan made out, according to which the exterior of the inside coil must be fine turned in order that it may be exactly larger than the bore of the outside coil by the required amount of shrinkage at the respective points.

Measurement and plan.

The plan, together with a series of corresponding "horse-shoe" gauges (very accurately adjusted), is then furnished to the turner who turns down the inside coil accordingly.

The reason an inner tube is turned to suit an exterior one instead of the latter being bored to suit the former is, that it is much easier to turn than to bore to very exact dimensions on account of the great command which the workman has over the turning lathe, and the facility he has of testing his work with gauges, and correcting it with emery powder and oil.

Why an inner tube is turned to suit an outer one.

The operation of shrinking is very simple; the outer coil is expanded by heat until it is sufficiently large (if a large mass, such as the jacket of a Fraser gun, by means of a wood fire for which the tube itself forms a flue; if a small mass, such as a coil, in a reverberatory furnace at a low temperature). It is then raised up by a travelling crane overhead and dropped over the part on to which it is to be shrunk, which is placed vertically in a pit ready to receive it.

The operation.

The heat required in shrinking is not very great. Wrought-iron on being heated from 62° F., (the ordinary temperature say) to 212°, expands linearly about $\frac{1}{1000}$th* part of its length (the same amount of extension in fact as that due to its elastic limit or pressure of 12 tons per square inch of section); that is to say, if a ring of iron 1,000 inches in circumference were put into a vat of boiling water it would increase to 1,001 inches; and according to Dulong and Petit, (see Ganot's Physics, translated by Atkinson, p. 206), the coefficient of expansion, which is constant up to 212°, increases more and more from that point upwards, so that if the iron ring were raised 150° higher still (*i.e.* to 362°) its circumference would be more than 1,002 inches. Now it has already been shown† that no coil is ever shrunk on with so great a shrinkage as the $\frac{2}{1000}$th part of its circumference or diameter, for it would be strained beyond its limit of elasticity; allowing therefore a good working margin it is only necessary to raise a coil to about 500° Fahr.‡ though in point of fact a good many are heated a good deal more than this in some parts on account of the mode of

Expansion of iron by heat.

High temperature not necessary.

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* According to Lavoisier and Laplace the linear expansion of wrought-iron on being heated from 32° F. to 212° is ·0012350 (see Phillips' Manual of Metallurgy, 2nd edition, p. 14), and according to Roy and Ramsden it is ·0012204 (*see* Ganot's Physics, translated by Atkinson, p. 205.) Taking it therefore as ·001 for 150°, cannot be far wrong.

† See Chapter II., p. 24.

‡ The temperature may be judged by colour; at 500° F. iron has a blackish appearance, at 575° it is blue, at 775° red in the dark, at 1500° cherry red, and so on getting lighter in colour, until it becomes white or fit for welding at about 3000°.

heating employed. Were a coil plunged in molten lead or boiling oil (600° F.) it would be uniformly and sufficiently expanded for all the practical purposes of shrinking, but as shrinkings do not take place in large numbers or at regular times, the improvised fire or ordinary furnace is the more economical mode and answers the purpose very well.

Heating a coil beyond the required amount is of no consequence provided it is not raised to such a degree of temperature that scales would form; and in all cases the interior must be swept clean of ashes, &c., with a broom when it is withdrawn from the fire.

Mode of cooling.

With respect to the mode of cooling during the process of shrinking, care must be taken to prevent a long coil or tube cooling simultaneously at both ends, for this would cause the middle portion to be drawn out to an undue state of longitudinal tension. In some cases therefore water is projected on one end of a coil so as to cool it first. In the case of a long tube of different thickness like the *B* tube of a R.M.L. gun, water is not only used at the thick end, but a ring of gas or a heated iron cylinder is applied at the thin or muzzle end, and when the thick end cools the gas or cylinder is withdrawn from the muzzle and the ring of water raised upwards slowly to cool the remainder of the tube gradually.

Cases where gas and water should be used.

A flow of water always inside.

As a rule the water is applied wherever there is a shoulder so that that portion may be cooled first and a close joint secured there; and invariably water is allowed to circulate through the interior of the mass to prevent its expanding and obstructing or delaying the operation; for example, when a *B* tube is to be shrunk on a steel barrel, the latter is placed upright on its breech end, and when the *B* tube is dropped down on it a continual flow of cold water is kept up in the barrel by means of a pipe and siphon at the muzzle. The same effect is produced by a water jet underneath, when it is necessary to place the steel tube muzzle downwards for the reception of a breech coil.

Broaching.

Necessity for.

A broach is the name of the tool used in mechanical arts for making a taper hole or for perfecting a cylindrical one.

During the process of boring, the cutters wear from friction so that the tube is always slightly taper inside. This is of no consequence in an outer tube as the interior one can be turned to suit it, but an inner barrel must of course be truly cylindrical, hence broaching is employed to remove the taper.

In the B.L. guns the operation was performed in a slightly sloping machine, and the broach commenced its work at the narrow or breech end (*i.e.*, the reverse of the boring process), but solid ended barrels are broached in the boring machine. The broaching-head is round and fitted with four long cutters fixed lengthways at right angles to each other and slightly tapering.

Broaching-head.

The cutters are carried round the front of the head and are shaped so as to finish the chamber of M.L. guns to the required form.

Lapping.

Necessity for.

Lapping or the process of making any hard surface smooth and accurate by the application of polishing powders is used in the Royal Gun Factories for finishing off the bore of an inner barrel, for notwithstanding fine boring and broaching some little roughness and irregu-

larity will exist. The process of rifling also often causes some of the metal on the edge of the grooves to be burred. Lapping is therefore performed both before and after rifling, also after proof.

The operation consists of working (by means of levers attached to a revolving bar) a wooden head covered with lead and smeared over with emery powder and oil, backwards and forwards in the bore wherever the very accurate gauges indicate the necessity.

"Laps made of nearly every metal and alloy in common use have been more or less employed as vehicles for the application of several of the polishing powders, but of all laps those of lead slightly hardened and supplied with powdered emery stone render the most conspicuous service." (Holtzapffel's Turning and Mechanical Manipulation.)

Rifling.

In order that the tool in the rifling machine may cut a spiral groove in the gun, it is necessary that it should have given to it a motion of rotation as well as that of progression. Did it simply progress along the bore, a straight groove would be made, and did it rotate without moving forward a ring would be cut round the bore. Now by combining these two motions and regulating the ratio of the rotation to the progression a spiral of any required pitch can be obtained.

The original machine.

In the rifling machines used for the earlier Armstrong B.L. guns there was no tangential or copying bar, but the grooves were cut by means of a four-sided bar with the corners rounded off, twisted at the required spiral. The bar and cutters were forced to revolve the necessary amount by the bar having to pass through a fixed nut near the muzzle of the gun as it moved down the bore. These bars were very expensive, and each spiral required a separate one, so the more universal machine now used was introduced.

This machine is horizontal, and the gun is fixed stationary in front of it, in line with the rifling bar. This bar is attached to a saddle through a nut in which passes a fixed screw stretching along the middle of the bed, as in the boring machines.

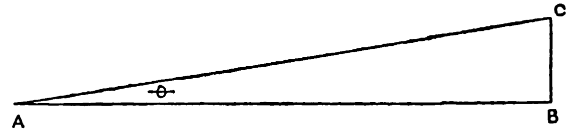
Method of obtaining the required pitch of rifling.

The forward and backward motion is given to the saddle by the revolution of this screw, and the motion is reversed in the manner previously described (see page 38). The rifling bar is carried by the saddle, but is capable of turning on its axis independently of it, the necessary rotation being obtained from a rack working at right angles to the bar, on a pinion fixed to its extremity. This rack is fitted with friction-wheels which run along the sides of a horizontal tangent or copying bar set at the required angle on one side of the machine, consequently as the saddle progresses, this rack being constrained to move along the copying bar is forced across the machine and gives the pinion on the rifling bar the required rotation. The amount of rotation varies, of course, with the angle at which the copying bar is inclined, and by a hinge at one end this angle can be altered, so that the copy may be used for different pitches of uniform rifling ; the greater the angle, the quicker does the rack slide and the bar revolve, and the sharper is the twist of the groove cut in the gun, but the greatest twist in any gun in the service does not amount to more than one half of a turn in the length of the bore. If the tangent bar be on the right side of the machine, and it is intended to give the gun right-handed rifling, the hinge is at the end next the gun. If on the other side it will be away from the gun, of course this is reversed if the rifling is left-handed.

Calculation of tangent bars for rifling machine.

(1.) Uniform rifling.

In the case of a uniform spiral, the copying bar is straight edged, and the angle is easily calculated thus:—



Take AB equal length of rifling due to one turn, *i.e.*, the distance travelled by the projectile while it is turning on its axis, and BC at right angles to it and equal length of one turn, or the circumference of the bore, then AC will be the total length of spiral, and θ the angle of the rifling and of the tangent bar. Let $n=$ number of calibres in which the shot makes one turn.

$$\tan\theta=\frac{BC}{AB}=\frac{\pi\times\text{calibre}}{\text{number of calibres}\times\text{calibre}}=\frac{\pi}{\text{number of calibres}}=\frac{\pi}{n}.$$

For example, take the 7-inch gun, whose spiral is one turn in 35 calibres, then

$$\tan\theta=\frac{\pi}{35}=\cdot0897;$$

$$\therefore\ \theta=5^\circ\,4'\text{ nearly.}$$

Did we require the actual amount of twist x in the bore, it is easily obtained from the proportion

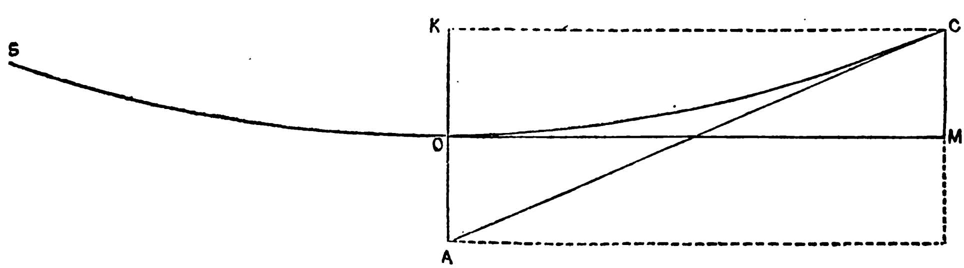
$$AB : BC :: l : x,$$

l being the length of the rifled part of the gun; and we can form a good idea of the course of the groove along the bore, by supposing the position which the line AC would assume were the above figure wrapped round a cylinder equal to AB in length and BC in circumference.

(2.) Increasing rifling.

For shunt rifling, as in the 64-prs., there must be a corresponding shunt on the copying bar, and for a uniformly increasing twist the edges of the bar must be curved accordingly; and as it is the property of the parabola to increase uniformly in curvature, we have adopted it as the curve of the rifling, its well known properties enabling us to construct without difficulty a copying bar for any required spiral.

Thus, suppose we want to make a copying bar for the 9-inch gun, which has an increasing twist from 0 at the breech to 1 in 45 at the muzzle.



Let us assume that OC is the required parabolic curve, and let OM drawn through the vertex of the parabola perpendicular to its axis, represent the length of the bore to be rifled, $=l$ suppose. The tangent at C makes an angle with OM or AB equal to the angle of rifling at

the muzzle, and cuts off (by the property of the parabola) OA on the axis equal to the abscissa OK.

$$\therefore \text{CM} = \text{MB} = \frac{\text{BC}}{2}.$$

Again—

$$\frac{\text{BC}}{\text{AB}} = \frac{\pi \times \text{calibre}}{\text{number of calibres} \times \text{calibre}} = \frac{\pi}{\text{number of calibres}} = \frac{\pi}{n}$$

Let $y^2 = px$ be the equation to the parabola,

Then $$\frac{y^2}{x} = p.$$

But at the muzzle $\text{OM} = y = l$

and $$\text{CM} = x = \frac{\text{BC}}{2}$$

$$\therefore \quad \frac{x}{y^2} = \frac{\text{CM}}{l^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a).$$

$$\text{Again } \frac{\text{BC}}{\text{AB}} = \frac{\pi}{n}$$

$$\therefore \quad \frac{2\,\text{CM}}{l} = \frac{\pi}{n} \text{ and } \text{CM} = \frac{\pi l}{2n}.$$

Substituting for CM in (a) we have

$$\frac{x}{y^2} = \frac{\text{CM}}{l^2} = \frac{\pi l}{l^2 \times 2n} = \frac{\pi}{2nl}$$

$\therefore x = \dfrac{\pi y^2}{2nl}$ is the equation required,*

---

* This formula can be arrived at very readily by using the calculus, as follows:—

Tangent of angle at muzzle $= \dfrac{\pi}{n}$,

$$\therefore \frac{dx}{dy} = \frac{\pi}{n}.$$

But $y^2 = px$ (1.) is equation to curve

$$\therefore \frac{dx}{dy} = \frac{2y}{p},$$

$$\therefore \frac{2y}{p} = \frac{\pi}{n},$$

$$\therefore p = \frac{2ny}{\pi} \quad . \quad . \quad . \quad . \quad (2.)$$

But if l = length of bore to be rifled, then $y = l$ at the muzzle, and the equation (2.) becomes—

$$p = \frac{2nl}{\pi} \quad . \quad . \quad . \quad . \quad (3.)$$

$\therefore$ substituting (3.) in equation (1.)

We have $y^2 = \dfrac{2nl}{\pi} x$,

$\therefore x = \dfrac{\pi y^2}{2nl}$. Q. E. D.

and by assuming different values for y, that is, different points at which we wish to calculate the curve of the bar, and substituting the proper values of π, n and l, we can find the x for that point.

For instance in the 9-inch gun,

$$n = 45 \text{ and } l = 107 \cdot 5 \text{ inches.}$$

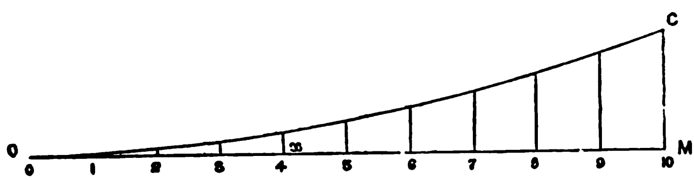
Let OM be the length of rifling and OC the curve required, then MC or x at the muzzle is found as follows :—

$$x = \frac{\pi y^2}{2nl} \text{ at muzzle } y = l$$

$$\therefore \text{MC} = \frac{\pi l}{2n} = \frac{3 \cdot 1416 \times 107 \cdot 5}{2 \times 45} \text{ inches} = 3 \cdot 75 \text{ inches.}$$

Suppose Ox=50 inches, then the height of the curve at the point x

$$= \frac{\pi y^2}{2nl} = \frac{3 \cdot 1416 \times (50)^2}{2 \times 45 \times 107 \cdot 5} = \cdot 81 \text{ inch.}$$



By this means the height of the curve can be calculated for any number of points, and a steel bar, cast for the purpose, placed with one end resting on a plane table, and the other end supported at a height from the table equal to MC, by means of the various measurements the curve is traced on it, and afterwards planed or slotted out.

If the pinion on the sliding rack and the bore of the gun are of the same diameter, the curves of the grooves and of the copying bar are the same ; but if, as is generally the case (for, excepting the copying part, the same machine answers for all calibres and systems), the pinion and bore are of different sizes, the curvature of the bar will differ proportionately from that of the grooves. Thus, if the pinion is half the size of the bore, the bar must have half the curvature of the grooves.

Method of varying the depth of groove. This copying arrangement enables us to regulate the pitch of the rifling, but it is also sometimes required that the depth of the groove should vary at different parts as, for instance, in the "shunt" rifling. Now the tool is withdrawn as the rifling head enters the bore and cuts only as it is coming out, a stout rim of bristles brushing out the chips before it. The withdrawal of the tool is effected in the following manner :—The rifling bar and head are hollow, and a spindle passes down inside the former, the end of which in the head has an inclined slot in it, in which works a small block carrying the tool, so that when the spindle is forced forward the tool is withdrawn, and when it is forced back again the tool is fed out. The end of the spindle is fixed to a small moveable slide attached to the saddle, but capable of moving independently of it. The movement of this slide (and consequently of the tool) is regulated by another copying arrangement on the other side of the machine. This arrangement consists of two horizontal bars, one higher than the other, along which travels a weighted lever attached to a pinion which works the slide. When the rifling head is passing down the bore this weighted lever travels along the upper bar,

but, when the machine is reversed the lever is prevented by a small moveable piece from returning on the same bar, so that the weight falls over on the lower one, and in doing so draws back the slide and spindle and forces the tool out. By varying the form of the upper surface of this lower bar the depth of the various parts of the groove can be regulated and altered as required.

All the grooves in the gun are first cut out roughly in succession, and then finely. The distance between the grooves is regulated by a disc fixed to the breech of the gun, having its periphery equally divided by as many notches as there are to be grooves. The gun is fixed each time by a pawl, and when a new groove has to be cut, is turned round to the next notch.

Pitch of rifling.

The pitch of rifling in any gun should not be greater than is necessary in order to obtain accurate shooting, as the wear of the grooves and the strain upon the gun are thereby increased, more particularly in the case of uniform rifling. The twist required to give good shooting, that is, to keep the axis of the projectile steady during its flight, depends mainly on its length and form, and also to a certain extent upon the velocity given to it. The longer the projectile in proportion to its diameter, and the lower its velocity, the more rapid must be the spin imparted to it; hence in the smaller natures of rifled guns, and in pieces intended for high angle firing, a greater twist is used than in heavy guns, as the velocity of their projectiles at long ranges is low.

The question of the best form of projectiles is discussed in the "Treatise on Ammunition, Part II.," by Captain C. O. Browne, R.A. (late Captain Instructor, Royal Laboratory), where it will be seen that the length of service projectiles (except double shell) varies from about 2¼ to 3 calibres, including the ogival head. With this form of projectile it has been ascertained by experiments that a twist of about one turn in thirty-five calibres ($\frac{1}{35}$) gives the best results, and that any material deviation from this amount in large guns tends to render the projectile more or less unsteady in its flight.

Advantages of increasing spiral.

In the uniformly increasing rifling adopted in large guns, the grooves have little or no twist at the seat of the shot, and the pitch of rifling gradually increases until it reaches its maximum at the muzzle. The advantages of this description of rifling are that the projectile, not being forced to take the whole twist of rifling at once, moves more readily from its seat, and thus the initial strain upon the breech of the gun is reduced. Moreover the studs on the projectile are not so liable to be torn off, or the edges of the grooves to be set up. It has, however, the disadvantage of giving less velocity, but the loss from this cause is very trifling.

The dimensions of the grooves and lands, and the twist of rifling for each nature of gun will be found in the tables (pages 77–147), whilst a full sized drawing of section of the grooves is given under the description of the guns in the service.

Drilling.

The cutting portion of a drill is flat and shaped like a broad V.

Small holes such as those for friction tube pins, &c., are drilled by hand, the tool being turned by means of a brace or ratchet lever; but larger holes such as those for sights and vents are made with a drilling machine, the shape of the cutter is however the same.

The self-acting machine.

The self-acting radial drilling machine is an ingenious piece of mechanism. The radial arm or "jib" carrying the drill spindle turns upon a bracket which can be raised or lowered as required. The motion to turn the drill spindle is derived from a cone-pulley behind

the sliding bracket through mitre gear. The horizontal adjustment of the drill slide is done by means of a screw turned by a handle at the end of the arm. The vertical feed of the spindle is given by separate mitre gear in connexion with the horizontal shaft, as well as by a rack and pinion which can be worked by hand independently.

In drilling the holes for the vent bush and sights of guns, this machine is very convenient as the gun can be placed anywhere within the area covered by the radial arm, and the drill accurately adjusted in the proper position without moving the gun.

Screw-Cutting.

A small internal screw thread, like that for vent bushes, is generally made by hand with taps.

Taps.

A tap is a steel tool converted from a screw by the removal of part of its circumference in order to give the exposed edges a cutting action, and allow room for the chips to escape, while the circular parts which remain guide the instrument within the helical groove or hollow thread it is required to form. In the Royal Gun Factories, three or four taps gradually increasing in size, are generally employed to make a screw thread, but mechanics often use only one taper tap.

A small external screw is cut by means of a screw die.

The machines.

Large external and internal screw threads, such as the male and female cascable thread, are executed in screw-cutting lathes either with traversing mandrills, in which case the work slides forward while the tool revolves, or with traversing tools when the work revolves and the tool moves forward. The principle is the same for both, but the latter is more in use. The guide screw which governs the sliding motion of the tool is parallel to the axis of the work when fixed in the machine and connected with it by means of toothed wheels. The screw upon the work will be the same pitch as the guide screw if both revolve at the same rate, and this will be the case if there are only two change-wheels (or a train whose value is 1) with the same number of teeth in each. If it is desired to cut a screw with twice the pitch of the guide, the work must be made to revolve twice as quickly as the latter, and so on for a thread of any pitch ; each lathe is therefore supplied with a series of change-wheels, in order that a screw thread of any pitch required may be cut in it.

Slotting and Planing.

When the edges or surfaces of iron work cannot be readily reduced to proper size and shape by filing, a slotting or planing machine is employed as circumstances warrant. For example, the sides of a trunnion-ring are planed, but its belt or interval between the trunnions (which cannot be brought to shape in a turning lathe) is slotted, and the usual way of making any non-circular hole—such as the vent slot—is first to drill one or more round holes, and then slot or pare the edges to shape.

The machines.

Every slotting and planing machine is self-acting, that is, it has a double action, by means of which the cutter and the work move reciprocally, so that a fresh cut is made every time. Thus in the slotting machine (which cuts vertically), while the tool is being moved up, the work is advanced just sufficient for another slice, and in the planing machine (which cuts horizontally), while the work returns to be cut the cutter slides across the necessary distance.

In the large machine used for slotting the surface of the gun between the trunnions, the motion of the tool is obtained by means of a peculiar

form of eccentric, giving a quick return. The table upon which the work rests can be fed either longitudinally, transversely, or circularly, and the feed is obtained from a horizontal groove cam on the spindle, which acts through a series of levers upon spur-wheels and screws in connexion with the table.

In the planing machine used in the Department the reversing motion is similar to that used in the boring and rifling machines, but bevel-wheels of different sizes being employed, the table travels faster on the return than when moving forward against the cutter, thus economising time.

Viewing and Gauging.

Examinations during the stages of manufacture.

The examining or viewing is a branch in itself, with foremen for each class of work, whose constant duty it is to examine every article carefully at the close of, and sometimes during each operation, to ascertain that it is manufactured properly, and to the correct dimensions. Thus the flat bars which form a pile are examined as to manufacture and size before they are heated for rolling; the rolled bar is examined before it is welded to others; the long bar is examined before and after it is coiled; the coil after it is welded, faced, recessed, bored, turned, &c.

Every gun, &c. is made from a working drawing, which shows the dimensions of the various parts.

No manufacturing limits are supposed to be allowed; any departure from the correct dimensions is noted, and if considered of consequence by the viewer it is submitted to the Superintendent, who passes or rejects it as he may think fit.

The bore and internal surfaces which have to be shrunk together, are measured by means of gauges and Whitworth's micrometers to $\frac{1}{1000}$th of an inch, which is the smallest measurement taken in the department.

Measurement of the bore.

A deviation of this amount in the bore can be directly ascertained by a bar gauge, provided with a self-registering micrometer scale. The bore of a B.L. gun is also tested at different parts with high and low cylindrical gauges. The former must not enter, the latter must pass through. Thus there are three pairs of gauges for a B.L. gun, viz., for the powder chamber, shot chamber, and the grip. The gauge for M.L. guns has studs corresponding to those on the projectiles in order that the grooves may also be tested. From the care taken during the manufacture to have the inner barrel and all the super-imposed parts properly centred in the boring and turning lathes, the bore of a built-up gun must be concentric with the exterior, and the trunnions must be in their proper position; hence Desagulier's instrument has almost fallen into disuse.

External measurements.

External dimensions are taken with callipers and measuring rods, but in this case $\frac{1}{100}$th of an inch is considered close enough.

The examination of guns after proof belongs to this branch, but the subject requires to be dealt with separately.

Before any gun or article, which is a separate store, is issued for service, it is examined by the Assistant Superintendent, who is responsible for its exact accordance with the sealed patterns.

The sealed patterns.

These standard patterns are sealed by the Director of Artillery and Stores for the War Office, to govern future supplies; and no one is allowed to touch them but the officials of the R.G.F., in whose charge they are.

CHAPTER V.

MANUFACTURE OF RIFLED B.L. GUNS AND THEIR FITTINGS.

Designation of rifled guns.—Parts of gun.—Materials of inner barrels.—*Manufacture of 40-pr. 35 cwt.*—Building up gun.—Operations after building up and before proof.—Rifling.—Chambering.—Coppering.—Renewing and repairing Breech bush Copper, &c. on service.—Bushing of 7-inch Guns.—Tin Cups.—*Breech Fittings,* Vent-piece.—Breech-screw.— Tappet Ring.— Lever and Keep-pins.— Indicator Ring.— *Wedge Guns.*—Advantages over Screw System.—Disadvantages.—Breech Fittings. — Stopper. — Wedge. — Locking Arrangement. — Rifling. — Venting.— Breech-bushing.—Proof of Rifled B.L. Guns.—*Sights and Sighting.*—Why sighted on both sides.—Barrel-headed and sliding-leaf Tangent Sights. — Graduation of Tangent Sights.—Calculation of "Permanent Angle of Deflection."—Clamping Arrangements.—" Drop " and " Screw " Trunnion Sights.—Process of Sighting. —*Method for Re-sighting Rifled B.L. Field Guns on service.*

Designation of Rifled Guns.

In all returns, reports, &c. of rifled ordnance, it is necessary to attend to the following rules :—

All rifled guns of 7-inch calibre and upwards should be designated by the calibre in inches; under 7-inch calibre by the weight of the projectile.

The calibre of a rifled gun is the diameter of the largest spherical projectile that can pass through the bore; the calibre of a B.L. gun is therefore the diameter of the grip, or smallest part of the bore.

The weight is stated in tons, if 5 tons or upwards, and in cwts., if under 5 tons. It should also be stated whether the gun is B.L. or M.L.

Examples :—

Rifled (or R.) M.L. 10-inch, 18 tons.
Rifled B.L. 7-inch, 82 cwt.
Rifled B.L. 40-pr., 35 cwt.
Rifled B.L. 40-pr. (wedge), 32 cwt.

See §§* 899 and 1081.

MANUFACTURE OF B.L. GUNS AND THEIR FITTINGS.†

Manufacture suspended, as M.L. guns are preferred.

The manufacture of B.L. guns has been suspended of late years because rifled M.L. guns are preferred for heavy ordnance, and there are enough of the smaller natures already made for field and boat purposes; moreover, muzzle-loaders are being gradually introduced for field artillery also, as three or four committees ‡ on the question have recommended their adoption, inasmuch as they are equal to

* The mark § refers to a paragraph in the "List of Changes in Artillery Matériel, " Small Arms, and other Military Stores," circulated every month by the War Office.

† Much of the information contained in this section has been obtained from MS. notes by Captain C. M. Molony, R.A., late Assistant Superintendent Royal Gun Factories.

‡ The Armstrong and Whitworth Committee, 1865; General Dacres' Committee on Field Artillery, 1866; the Committee on Field Equipment for India, 869; and the Dartmoor Committee, 1869. (*See* " Chapter I.," pp. 8 to 11.)

breech-loaders in range and accuracy, and much superior to them in the simplicity of their fittings and ammunition, as well as in their non-liability to wear. However, the present generation of gunners will have a good deal to do with the breech-loaders, and it is therefore necessary that they should thoroughly understand their construction and the method of repairing them.

There are two sorts of B.L. guns in the service, viz., the ordinary ones with breech-screws, and the wedge. The latter were introduced as an improvement on the former in the breech-closing arrangement, but their manufacture was soon stopped owing to the adoption of M.L. guns. There are only two natures of wedge guns (64-prs. and 40-prs.); a few only were made, and there are fewer still in actual use.

Wedge guns, why adopted, and why manufacture stopped.

Manufacture of B.L. Guns.

All the B.L. guns in the service have been made on Sir W. Armstrong's original construction, and all are—except a few which have steel barrels—completely of wrought-iron.

The 3-pr. B.L. gun submitted by Sir W. Armstrong in 1855 had a steel barrel, but that material was abandoned, owing to the difficulty of getting it of suitable quality at that time.

A B.L. gun consists of an inner barrel, a forged breech-piece, a forged trunnion-piece, and one or more coils according to its size. For example, the 6-pr. has one coil, and the 7-inch of 82 cwt. has six coils.

Component parts.

The inner barrel is generally made up of coils joined together in the usual way, but a number of guns—more especially 7-inch of 82 cwt., 20-prs. of 13 cwt., and 12-prs.—have inner barrels made out of solid forgings, *i.e.*, solid cylinders of wrought-iron afterwards bored out. These were adopted some years ago owing to the difficulty then experienced of making a coiled barrel free from defective welds, but the forged barrels were soon abandoned, for although they presented a clean inner surface, the fibre which ran lengthways was in the worst direction for circumferential strength, and the rush of gas tended much more rapidly to develope any flaws or defective welds; moreover, a better coiling iron was procured.

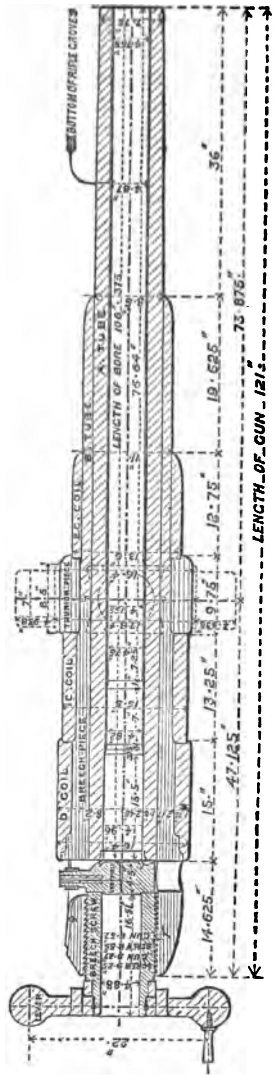
The annexed table gives the number of the guns in the service, with the various kinds of barrels:—

Nature.	Barrels.			Total.
	Coiled.	Solid forged.	Steel.	
Breech-Screw.				
7-inch 82 cwt.	699	179	5	883
7-inch 72 "	35	41	—	76
40-prs. 35 "	791	—	28	819
40-prs. 32 "	194	—	—	194
20-prs. 16 "	83	—	6	89
20-prs. 15 "	26	—	5	31
20-prs. 13 "	100	187	5	292
12 pr., 8 "	294	286	121	701
9-pr., 6 "	261	5	—	266
6-pr., 3 "	80	—	18	98
Wedge.				
64-prs., 61 cwt.	101	—	—	101
40-prs., 32 "	52	—	—	52

The manufacture may be divided into three distinct phases, viz. :—
(1.) The processes or operations until the gun is built up.
(2.) The processes after the gun is built up and before proof.
(3.) The processes after proof.

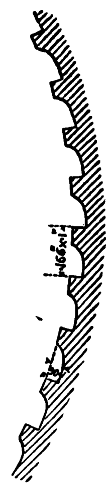
Manufacture of the 40-pr. of 35 cwt.

As an example of construction we will take the 40-pr. of 35 cwt.



Wrought-Iron B.L. Gun (Breech-Screw) 40-pr., 35 cwt., Mark I.

Scale $\frac{1}{24}$.



Section of Rifling (Full size).

The inner barrel, or *A* tube,* consists of five coils joined together endways; it is then bored and turned both roughly and finely, but it is not

* In the original construction of built-up guns, the letters of the alphabet were used to distinguish the different layers of metal. Thus the inner barrel is called the "A tube," the layer next outside of it "B," the next "C," and so on. It has been necessary to modify this nomenclature in the present construction.

finished turned until the *B* tube is bored and gauged and ready to be shrunk over it.

The B tube consists of a forged breech-piece united to two coils, and when shrunk on comes to within a yard of the muzzle. It is shrunk on to the *A* tube as described under the head of shrinking. The mass has then to be moved to the turnery and turned down according to gauge for the *D* coil. This is shrunk on, the mass is next turned down for the 1 *C* coil, which is shrunk on, and so on for the trunnion-ring and 2 *C* coil. Building up the gun.

The trunnion-ring after forging goes through the following machine operations before it is shrunk on:— Trunnion-ring.

(1.) Planing the sides.
(2.) Rough boring.
(3.) Turning the trunnions.
(4.) Fine boring.
(5.) Shaping.
(6.) Gauging the interior.

(Some 40-prs. of 32 cwt. have cast-iron trunnion-rings for the sake of economy. These may be known by the faces of the trunnions being bored out.)

Thus the building up of the gun is completed, and at this stage it may be finished either as a B.L. or M.L. piece; for instance, several 64-pr. guns were made up to this point, and were intended for B.L. wedge guns, but they were completed as M.L. guns, and this accounts for the similarity in the outline of the 64-pr. wedge and 64-pr. shunt gun (Mark I.).

Principal Operations after the Gun has been built up, and before Proof, exclusively of Manufacture of the Breech Fittings.

Turning Bearings on Gun. Final Boring. Broaching.

The first thing is to turn true bearings on the gun for the after machine processes. The gun is then finally bored in a vertical machine. The tool commences to cut at the muzzle of the gun, the bore being brought as nearly as possible to its true diameter, but as in travelling down the gun the cutters wear slightly, the bore is really taper to the same extent. The difference in the 40-pr. is about ·03 of an inch, and this necessitates the process of broaching. The tool for this purpose is very finely adjusted, and commences to cut at the breech (or the reverse of the boring process) and takes out the taper left by the boring tool, leaving the bore a true cylinder. **Operations after building up and before proof.**

Turning and Facing the Exterior.

At this stage the outside of the gun is finished by being turned all over and brought to its right length, and having the corners rounded off. The only part of the outside not turned in this process is the trunnion-ring which has been previously finished.

Rifling.

In his B.L. guns Sir W. Armstrong put as many grooves as he could, so as to distribute the friction as equally as possible over the whole surface of the bore, and also so as to have as thin a lead coating as possible on the projectile. These grooves are very nearly the same size in every description of Armstrong B.L. ordnance, the number varies in proportion Number and shape of grooves varies.

to the calibre, *e.g.*, the 6-pr. has 32, and the 7″ has 76. The driving edge, *i.e.*, the edge against which the shot is continually bearing as it comes out, is a straight line radial to the centre of the bore; and the other side is rounded to the land (see page 59). The 40-pr. has 56 grooves, and the twist in this latter gun is one turn in 36½ calibres. The remaining guns have a somewhat similar twist, the quickest being that of the 6-pr. which is one turn in 30 calibres, and the slowest that of the 64-pr. (wedge) which is one turn in 40 calibres.

In the process of rifling the grooves are cut to the very end of the bore, but afterwards in forming the chambers they are completely cut out in the powder chamber and rendered shallow in the shot chamber.

Drilling the Vent Chamber and Water Escape. Slotting the Vent Chamber.

Two separate holes intersecting each other are drilled at the proper place for the vent chamber, and these holes are afterwards slotted into one rectangular opening to form the chamber. Its dimensions in the 40-pr. are 4¾″ × 6½″.

At the bottom of the gun opposite this vent chamber is drilled a circular hole called the "water escape" or "drip-hole." This drip-hole is not the same size and shape in all the natures.

Facing the end of the A tube, and screwing for Breech Bush Copper.

The end of the *A* tube is smoothed, and a thread cut in the end of the barrel to receive the breech bush copper in the after process of coppering.

Boring for Breech-screw. Breech-screwing.

The end of the breech-piece is bored out and a female screw cut in it.

Advantage of the bevelled thread.

In the 40-pr. of 35 cwt. the pitch is ·7 of an inch and the depth is ·35 of an inch. This is called the *V* bevelled thread, which is used on account of its being stronger than a rectangular thread in resisting the concussive strains to which it is subjected. It is also easier worked and less liable to jam from dirt than the rectangular thread which was at first used, but this old pattern is still to be found in some 40-pr. B.L. guns of 32 cwt.

In the 7-inch there is a double thread, which, though only requiring the same time and power to screw it up as a single thread, is twice as strong.

Chambering.

Four different diameters.

The bore has four different diameters, the greatest, for the convenience of loading, is that of the powder chamber, in front of this is the shot chamber where the projectile lies, immediately in front of the shot chamber is the grip, which is the smallest of all, in order that the projectile may take the rifling at once; from the grip to the muzzle the bore is lapped out ·005 of an inch for the purpose of easing the gun.

The 40-pr. bore is 4″·75, whilst the shot chamber is 4″·82, and the powder chamber 4″·96. This difference completely obliterates the rifling in the powder chamber. The shot chamber is coned so as to nip the shot in the proper position, and the shot is shaped to correspond. When the gun is fired, the lead is compressed between the grooves ·07 of an inch or 4″·82—4″·75 as above. These last figures therefore represent the true diameter of the bore (*i.e.* the grip).

Coppering.

All the B.L. guns, except the 7″ and wedge guns, have a ring of copper screwed in the breech end of the *A* tube; there is a corresponding ring on the face of the vent-piece. These rings are respectively called the "breech bush copper" and the "vent-piece copper ring." Their object is to ensure a close fit, to prevent any escape of gas, and also to facilitate the repair of the tube where there is the greatest wear and expansion. They are coned in opposite directions so as to fit closely into one another. **Object of the copper rings.**

The copper is the purest obtainable, and is brought to the Gun Factories in long cylindrical bars 2″·5 in diameter. When required, a portion is cut off according to the size of the ring, that for the 40-pr. is 3 inches long. It is first heated and hammered down to 1¼ inch in thickness and 4 inches in diameter to make the copper compact, dense, and hard, and to destroy its malleability; should any slight cracks appear in this process they must be cut out to prevent their going further. A hole of 1½ inch diameter being next drilled through the disc, and a steel mandril put through it, it is cold hammered out between a steam hammer and this mandril until it is in the form of a ring. It is then turned, bored, faced, and slightly coned, and struck with a tilt hammer round the part that has been coned to make it more compact there. It is then finished turned, bored, faced, and screwed, and four little feather ways are cut in the inside to facilitate the screwing of it into the gun. **Manufacture.**

A vent-piece copper ring goes through somewhat similar processes, save that its shape is different. **Vent-piece ring.**

The face which is to fit against the *A* tube being red leaded it is screwed into the gun as a trial, and on being unscrewed, if the red lead shows it does not fit all round, it is scraped or filed down on the high parts. It is important that the face should fit perfectly tight to the barrel, for if the slightest space be left, the powder gas would eat into it. On being screwed in finally it is steadily struck home by a hand-spike, &c. The ring is then upset with the upsetting block; it is next bored out, for which purpose a bearing having been put into the bore in front of the bush for the boring spindle to work upon, the spindle is introduced through the breech-screw, there being two bearings in the breech-screw, one in front, and one behind, and the knife is fixed through the spindle in the vent chamber; the spindle is turned by a wrench and fed to its work by means of the breech-screw. After boring, a different tool is fitted through the spindle, and the copper is faced to within ·03 of an inch of the face of the *A* tube, the cone part being left ·15 broad. **Inserting a breech bush copper.**

For refacing or renewing these rings as they wear on service facing implements with instructions are issued (see page 183, Chapter XII.).

The 7″ guns were originally bushed with copper, which was afterwards superseded by an iron bush of the same size, viz., 2″ long, ½″ thick, this was again superseded by another iron bush 3″ long, ¼″ thick, as the short one was liable to shift. Guns so bushed are called double bushed, and are marked D.B. on the right trunnion. Some guns may still be met with at out-stations which retain the copper bush or the thick iron bush. These can only be double bushed in the Royal Gun Factories, but those that retain the copper bush should be bushed with iron when practicable. **Exceptional bushing of 7-inch guns.**

Tin cups *must* be used with 7-inch and wedge guns to stop the escape of gas; they are sometimes used with the smaller natures also, not of necessity but as a protection to the copper rings, in order that they may not require refacing so frequently.* **Tin cups.**

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* Tin cups are ordered to be used with the smaller B.L. guns during practice, one cup being issued for every ten rounds, except the 64-pr., for which the allowance is one to every four rounds, §§ 1794 and 1848.

Lapping.

The grip.

About ·005 of an inch in the diameter of the bore is lapped out, as described, from the muzzle to 7¼ inches in front of the shot chamber, the object being to decrease the friction between the projectile and the gun after the former has fully taken the rifling. Until 1863 the shot was again gripped at the muzzle, but this has been removed from all the guns which had it, as it sometimes caused the premature explosion of the shell.

The body of the gun is now complete and ready for proof.

THE BREECH FITTINGS FOR BREECH-SCREW GUNS.

Vent-piece.
Breech-screw.
Tappet ring.
Lever and keep-pins.
Indicator ring.

Vent-piece.

Vent-piece. So called because the vent happens to go through it; is a block of wrought-iron which closes the end of the breech before firing; it ought to be more properly called the breech stopper.

Material. The material of vent-pieces has been changed so frequently it is hard to give their history, but we may say that first wrought-iron was used, then steel, then Swedish iron, then steel toughened in oil, and lastly, Marshall's refined iron.

Weights of vent-pieces—

Weight.

	cwt.	qr.	lb.
7-in.	1	—	24
40-pr.	—	2	3
20-pr.	—	—	27¾
12-pr.	—	—	15
9-pr.	—	—	14¾
6-pr.	—	—	8¼

The vent-pieces of all natures except the 7″ and 40-pr. are lifted away from the gun after each round, the others are placed on the saddle or vent rest.

A vent-piece consists of—

Component parts.

Body.
Vent bush copper (in two parts).
Vent-piece copper ring (except 7″).
Cross-head.
Shackles.

There is a "beak" on the 7″ and 40-pr. to prevent the "nose" on the face being injured when the vent-piece is being put in.

A vent-piece having been solid forged is turned and machined into shape and sent to the fitters who finish it off; that part of the back against which the breech-screw fits and the face are brought to the correct figure.

Bushing with copper. The vent channel is bushed with copper at the upper end where the friction tube rests. (It would weaken it too much to bush the lower end or horizontal portion.) The bush formerly consisted of three or four short plain pieces, and one screwed piece on the top, but now one long plain piece is used instead of the short ones.

The bushes are made from a bar of best copper; the end of the bottom of the bush is slightly concave as being the best form to resist the action of the powder. The top piece has a screw and a square head by which the whole is screwed down. The plain piece is riveted down by a hammer thus fitting closer than if screwed in, the top piece is then screwed in with a wrench by two men until the nut is wrenched off; it is again riveted with a hammer, cut and filed off, and re-drilled to the proper size of the vent, which makes the vent coincident in both pieces.

The vent-piece is next put into a screw press and the copper ring is forced on, a small amount being left projecting to allow for refacing on service.

The vent ring. The section of the ring is half dovetailed in shape so as best to retain its hold on the vent-piece.

Cross-head and shackles. The cross-head and shackles are not put on till after proof. The cross-head is made from a block of scrap iron, it is so shaped that its projections rest on the slot when the vent is properly placed for being screwed up. Great pains are taken to get this correct to prevent the possibility of the vent-piece going wrong, so the men should let go of it before screwing up.

The screw on the cross-head is a very tight fit to the neck, requiring two men with a wrench to get it home; when it is home a small hole is drilled half an inch in each of the threads, and it is pinned down; this is necessary as many cross-heads have been blown off.

The shackles are made from a bar of scrap iron and attached to the cross-head by pins.

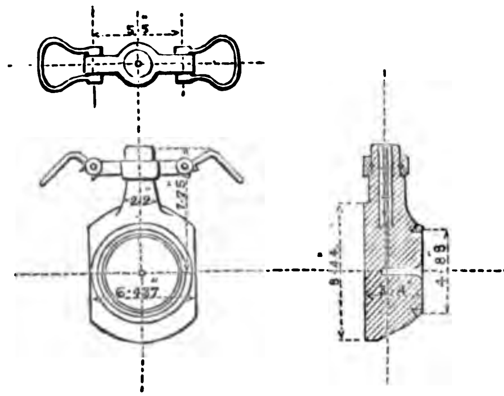
The 40-pr. vent-piece may be taken as a type of the rest, except that of the 7-inch, which has no copper ring but a more projecting face which fits into the end of the *A* tube.

Advantages and disadvantages of the vent through the breech stopper. The advantages of having a vent through the breech stopper are that the gun is not weakened by being bored for the reception of a copper bush, and is unaffected by any damage to the vent; in case of accident a new vent-piece can be supplied. On the other hand the gun frequently hangs fire, which some attribute to the vent not being straight, and others to the bushing having moved and the vent not remaining coincident throughout; another disadvantage is that the vent-piece becomes weakened by being bored, and ultimately more so as the channel becomes worn (often to ten times its size). The gas passing through the channel in the vent sometimes blows off the neck and shackles; another disadvantage is the great expense. Experiments have been carried on with some 7-inch guns to test the proposal of having a vent through the gun, and a solid stopper or plugged vent-piece, and the results have been favourable. As the B.L. guns are being superseded by M.L. ordnance and no more will be manufactured, the question has been allowed to drop.

Important order. The material, date of manufacture, pattern, and R.G.F. number are marked on the back; and the order is, that the latest pattern available should be used, and one without a projection at the back, should never

(if possible) be used. An old pattern vent-piece, having a flat back is shown below.

OBSOLETE VENT-PIECE. Scale 1 in. = 1 foot.



Breech-screw.

Breech-screw. **Material.** Is made of steel, toughened in oil for all B.L. guns, except the 7-inch which has an iron breech-screw with a steel face 6″ long screwed into it, an iron face being liable to "set up." **Thread.** The thread is called the "*V* bevelled" from the shape of its section, which is stronger than the square thread used in the early Armstrong guns, and also more easily worked. Some of the square thread breech-screws are still to be found in use, and formerly the tappet rings were secured with keep-pins. The ends of the thread are not left sharp but cut off at about half their thickness. The 7-inch breech-screw has a double thread.

Weight. Weight of breech-screw complete, with lever, tappet ring, and keep-pins :—

	cwt.	qr.	lb.	Pitch of thread. Inch.
7-inch	5	2	18	1·4
40-pr.	2	1	13	0·9—32 cwt gun. 0·7—35 „
20-pr.	1	0	8¾	0·5
12-pr.	0	2	12	0·5
9-pr.	0	2	6¾	0·5
6-pr.	0	1	10	0·5

Processes of manufacture. Steel breech-screws are cast, and after being rough bored and turned are tempered in oil. They are then fine bored, faced, the octagon shaped, and the screw cut in a copying machine similar to that for cutting the screw in the gun, but having an outside screw to cut it can be done with more facility than an inside one, as one tool cuts the screw going up, another when it is returning. The pitch is of course the same as that of the gun, but the height and thickness of the thread is not the same, for it is necessary to have a good deal of play to the breech-screw for facility of screwing up, and also in case of any grit falling on it, this difference in breadth and depth is ·02 inch. After the screw is made the octagon is cut in a planing machine, the eight sides being cut in succession through means of a "dividing plane," by which the piece is turned one-eighth of a circle each time.

The operations by hand are as follows:—

The thin end of the thread is cut off at both ends until it is about half the breadth of the full one. The octagon is finished off by hand. The bore of the breech-screw is rounded off for loading. The feather for the

indicator ring is also put on, and the whole of the breech-screw is finished off with emery cloth. The screw is marked for the nature of gun, but not for an individual gun, thus:—

40-pr. R. G. F. W. ↑ D. F. 49. steel tempered.

Marks on. The F. 49 refers to the registered number of the breech-screw in the R. G. F. books.

The 7-inch breech-screw is made of wrought-iron forged from scrap like the breech-pieces.

Breech-screws are interchangeable amongst all guns of the same calibre, except between the 40-prs. of 32 cwt., which still retain the the old square thread, and those 40 prs. which have the bevel thread.

The bore of screws is slightly less than that of the powder chamber, in order that the breech bush shall not be damaged by the nose of the projectile when loading.

Tappet Ring.

Tappet Ring. Is octagonal in shape in the interior, and fits on a similar octagon on the breech-screw; hence it acts as a wrench to the breech-screw, the power being communicated through its projections from the tappets of the lever.

Processes of manufacture. It is made of wrought-iron. The 7″ and 40-pr. have two short projections opposite to each other; all other natures have one long projection. They are interchangeable for guns of the same calibre.

After being forged they are turned and machined to the proper size and shape, the octagon being formed by means of a "dividing plane," several tappet rings being slotted at one time in a vertical machine. The tappets on the ring are part of the forging, and not added afterwards as in the case of the lever.

Lever and Keep-pins.

Lever and Keep-pins. The lever fits on the breech-screw behind the tappet ring; it is free to revolve round the breech-screw, but is prevented from falling off by two keep-pins which work in a cannelure. The lever is fitted with weight balls or accumulators, to give power in screwing up. The levers are all of wrought-iron forged, the handles and tappets being forged separately. The small natures up to the 20-pr. inclusive have one handle, one weight ball, and one projection. 40-prs. have one handle, two weight balls, and two projections. 7-inch guns have two handles, two weight balls, and two projections. The levers have all a play of ·02 inch running round the breech-screw, and as there is no particular strain on the levers, they are not easily damaged; they are interchangeable for guns of the same calibre.

Processes of manufacture. Levers and tappets for all natures used to be forged by being stamped in dies; but this was objectionable in the case of large levers, as the metal was chilled by the die; small levers, however, are still stamped (up to 20-pr.), the others are forged from slabs as follows:—

Four small slabs are joined to a porter bar and in one heat are drawn down roughly; another heat is then taken, a hole is made which is rounded to the proper size by a succession of increasing punches, and kept to its proper size by swages. The lever is now finished with the exception of the ends of the arms where there is not sufficient metal to form the balls for which a piece of iron of sufficient size must be heated and wrapped round the end of each arm, and pressed into the shape of a ball with swages. The holes are drilled for the tappets on the lever, which are countersunk in order that they may be riveted. The channels for the keep-pins are drilled by a "jig" (a jig is an accurately

made guide by means of which the work that is fixed on to it must be truly copied).

The finishing of the levers by fitters includes finishing the ends of the balls, fitting in the projections and riveting them, running the holes for the keep-pins, the screw, and handles.

Keep-pins.

The keep-pins are steel, one end of which is flat, the other end rounded; they are slotted near the centre, and punched out so as to form a spring to keep them in their places.

Indicator Ring.

Indicator Ring.

Is a thin narrow ring of wrought-iron fitted on the breech-screw in front of the tappet ring; on the internal circumference there are a series of grooves, any one of which fits a "feather" on the breech-screw; it is so adjusted on the screw that when the vent-piece is properly screwed up, the raised line of brass on the ring and on the top end of the breech-piece must coincide, and then it can be seen at a glance whether the vent is properly screwed up. As the copper rings and breech-screw are faced on service, the position of the raised line of brass must be altered to correspond by shifting the ring round on the breech-screw.

The 7-inch and 40-pr. are the only guns with which an indicator ring is considered necessary.*

WEDGE GUNS.

Wedge Guns.

There are only two natures in the service, viz., the 64-pr. of 61 cwt. and the 40-pr. of 32 cwt.

These guns are built and rifled on precisely the same principle as the breech-screw guns, and differ only in the system of closing the breech, and in being vented through the body of the piece.

Advantages.

The advantages claimed for wedge guns over the breech-screw system are—

(1.) Greater facility and less labour for working the gun.
(2.) Little or no escape of gas.
(3.) Impossibility of firing till the wedge and stopper are secured.
(4.) Greater simplicity in the fittings.
(5.) The detachment not so much exposed.

Objections.

The objections are—

(1.) Liability to injury owing to the wedge making an effort to free itself—when the gun is fired—from the breech slot.
(2.) Liability of wedge and stopper to become jammed with dirt, &c.

This second objection, which is the principal one, does not tell so much on board ship.

The breech-loading arrangement.

The peculiarity of the breech-loading arrangement is as follows:—The breech of the gun is slotted through from side to side. In the slot works a "moveable stopper and a moveable wedge."

Stopper.

The stopper is made of hardened steel, weighing in the 64-pr. (about) 57 lbs., and in the 40-pr. 27 lbs. It has a projecting face which fits into the end of the bore when loaded. A stud is screwed into the centre of the face, on which a tin cup is hung to prevent the escape of gas. There are two round studs at the top and one at the bottom, which travel along grooves in the slot, which are so arranged that the stopper finds its way in and out as required when moved in the direction. It cannot be detached from the slot accidentally, as a gun-metal drop pin or "stop" which passes through the upper surface of the gun has to be raised before it can be extracted. The back of the

* Some 40-prs. of 32 cwt. do not use them, not having sufficient length of breech-screw. (See § 1033, "Changes in Patterns.")

stopper is perfectly flat and at right angles to the axis of the bore when in the position for firing.

Wedge. Behind the stopper works a wedge which is of wrought-iron, weighing in the 64 pr. (about) $1\frac{1}{2}$ cwt., and in the 40-pr. 1 cwt. The front of this wedge is at right angles to the axis of the gun, but at its back there is a taper of half an inch in its whole length, and a corresponding taper in the gun at the back of the slot. It is worked in and out by a pair of moveable handles connected by bars—one at the top and one at the bottom—moving in grooves in the wedge; and these handles have a play of about 4 inches on either side, so that a little impetus can be given if necessary. At the bottom of the wedge, and running its length, is a projection working in a taper groove in the slot. The wedge cannot be accidentally withdrawn, being prevented by two projections in the back part of the slot at the top, one on the right side, the other on the left.

To remove the wedge the stopper must first be taken out, then draw the wedge out from the right side till it comes up against the projection, move the wedge slightly to the right, which will clear this projection, and it can then be withdrawn.

The wedge is not solid throughout, as the gun has to be loaded through the end of it, and on the lower surface of the front edge there is a cut off corner to allow water or fouling to escape.

Small pieces of hardened steel are let into the wedge at those parts where it strikes against the gun in working.

Locking arrangement. In order that the gun shall not be fired before the breech is properly secured, the vent cannot be uncovered until the stopper and wedge are in their places. A sliding plate moves in a brass frame screwed on the top of the gun behind the vent, covers it for loading and uncovers it for firing. The motion of this slide backward or forward causes a hardened steel "locking pin" to be lowered or raised.

This locking pin passes vertically through the gun into the slot, and there is a recess (about $\frac{1}{2}''$ deep) in the wedge and hammer, so that the wedge and hammer must coincide in the centre before this bolt or locking pin can fall into the recess, and until this pin is in the recess, the slide plate—which forces the pin down—cannot be withdrawn from over the vent. On the other hand, until the vent is covered with the slide plate, the wedge and stopper are immoveable, as the end of the pin can only be removed from them by the slide plate being pushed over the vent.

Rifling. The wedge guns are rifled on the same system as the breech-screw guns, with about the same twist. There are 70 grooves in the 64-pr. and 56 in the 40-pr.; they have also the differences in diameter of bore as regards the grip, and the shot and powder chambers; and the 40-pr. takes the same ammunition as the 40-pr. breech-screw gun.

Venting.* These guns are vented through the body (at an angle of 12°) similar to cast-iron ordnance. The vent bushes are of copper, but in three pieces, the bottom piece has an inverted cone at the end; this piece is put in first from the inside of the bore, and driven up as tightly as possible by means of wedges. The intermediate piece is dropped in from the top and set down tightly by hammering; and lastly, the top piece is screwed in.

Breech-bushing.* The wedge guns have hardened steel breech bushes at the end of the barrel, both to resist expansion and also in order that they can be repaired when necessary at that part. In the breech-screw guns, should expansion take place, the breech can always be properly secured by forcing the vent-piece further home. In the wedge guns, however,

* Both of these operations must be performed in the R.G.F., as there are no tools issued by which they could be carried out on service.

the position of the wedge and stopper being always the same when closed for firing, any expansion of the rear end of the chamber would cause an escape of gas.

The 40-pr. has a thin bush 1¾″ long by ⅛″ thick, which is screwed in.

The 64-pr. has a double bush, the outer one is thicker than the inner, and is forced in very tightly (not screwed), the inner one is screwed into it and a little further into the gun. Some of these 64-prs. have bushes 4″ long, others 3·4″ as the 4″ cut into the copper vent.

Proof of B.L. guns and fittings.

Proof of B.L. Guns and fittings.

A B.L. gun is proved without its breech closing apparatus (spare being used) by firing six rounds of 1½ the service charge, and the service shot.

Vent-pieces, breech-screws, stoppers, and wedges, undergo two service rounds.

Processes after Proof.

The principal processes after proof are :—

Sighting.
Engraving, &c., &c., as for rifle M.L. guns † (see page 111).
Painting or browning.

Nature of Tangent Sights* and particulars of Graduations for Rifled B.L. Guns.

Nature of Gun.	Permanent angle of Deflection of Sights.	Length of Radius in Inches.	Graduations for Degrees. Number.	Graduations for Degrees. Length in Inches.	Graduations for Yards. Number.	Graduations for Yards. Charge in lbs.	Graduations for Yards. Length in Inches.	Remarks.
7-inch B.L. 82 cwts.	2° 16′	45	15	12·057	3,600	11	8·286	
7-inch B.L. 72 cwts.		41·2	10	7·36	—	—	—	
64-pr. Wedge B.L.		38	15	10·05	3,400	8	7·099	Side.
		38·1	5	3·35	1,900	8	3·447	Centre.
40-pr. Wedge B.L.		32·375	15	8·565	—	—	—	No yard graduations.
40-pr. B.L., 32 and 35 cwts.		45	15	12·057	3,800	5	8·4319	
20-pr. B.L. 16 cwts.		36·2	12	7·656	3,500	2½	6·923	
20-pr. B.L. 15 and 13 cwts.		23·45	15	6·195	3,000	2½	4·2373	
12-pr. B.L., 8 cwts.		32·375	10	5·71	3,400	1½	6·033	
9-pr. B.L., 6 cwts.		23·45	15	6·195	3,000	1¼	4·044	
6-pr. B.L., 3 cwts.		23·45	15	6·195	3,000	¾	4·506	

* Besides tangent sights, the Rifled B.L. guns for S.S. down to 20-prs. inclusive, are supplied with wood side scales (giving 12° elevation and 6° depression) similar to those for S.B. guns.

Note.—The metal heads of the sights are not to be polished, as it would eventually destroy their accuracy.

Sights and Sighting.

A B.L. gun being sighted on both sides has four sights, namely, two tangent sights and two trunnion sights. The 64-pr. (wedge) has in addition a pair of centre sights like the rifled M.L. guns, viz., a short hexagonal hind sight and a short drop trunnion sight.

The reasons why these guns are sighted on both sides, are as follows :—

(1.) The tangent and trunnion sights can be used at any elevation; for being placed at the side of the gun the muzzle of the piece does not interfere with the line of sight when laying, and therefore the additional

† In the 7-inch and 40-pr. the slope for the vent-piece to rest on, in loading, is cut by a shaping machine, after proof; and the side edges of the slot are very carefully rounded by hand, so as to fit exactly the under curve of the cross-head.

scale graduated for the long radius for cast-iron S.B. guns is dispensed with in the case of rifled guns.

(2.) The issue of sighting instruments and spare sights to field batteries is unnecessary, for should a sight become unserviceable, no delay is caused by the preparation of another, seeing that the gun may be laid by the other side.

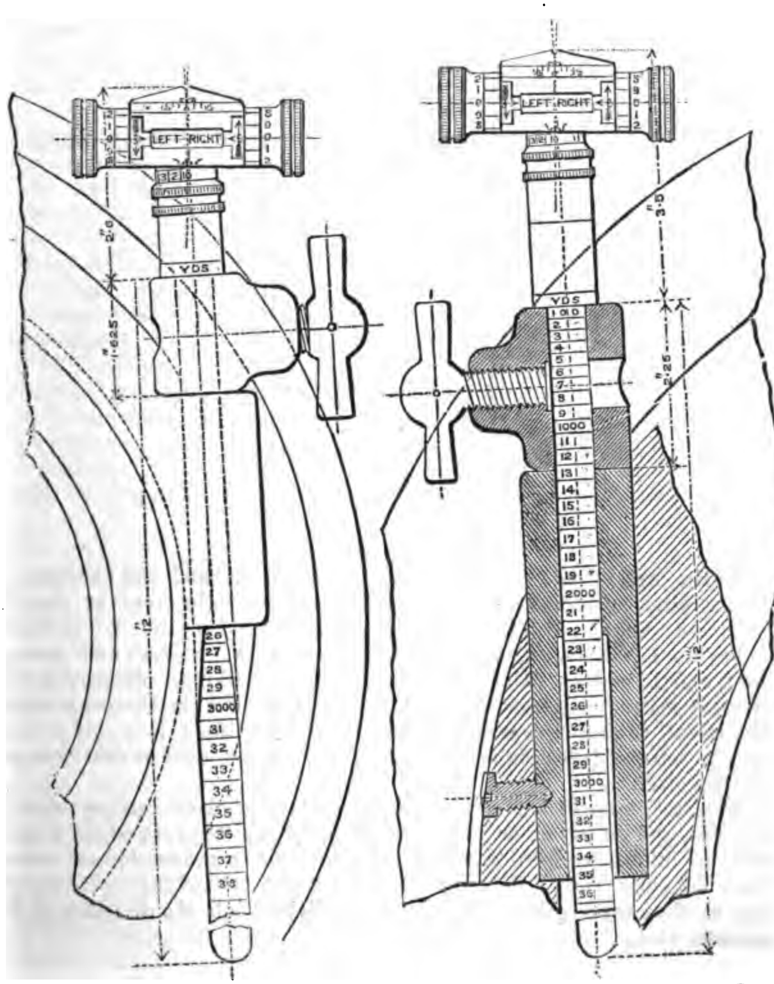
(3.) With guns mounted in forts or on board ships, in the case of extreme traversing, the sides of the embrazure or port, would render the sights on the side of the gun (nearest the work or side of the ship) useless, therefore the sights on the reverse side are ready for laying.

Tangent Sights. The present pattern tangent sights have rectangular steel bars with gun-metal "sliding leaf" cross-heads, but as the stock in store of the barrel-headed sights must be used up, they are still used with B.L. guns (especially in the land service), instead of the new pattern with the sliding leaf head.

Barrel-headed Sights, with moveable Clamp.

Scale $\frac{3}{8}'' = 1$ foot.

R.B.L. (breech-screw) 40-pr., 35 and 32 cwt. — R.B.L. 7″ 82 cwt. (with gun-metal socket).



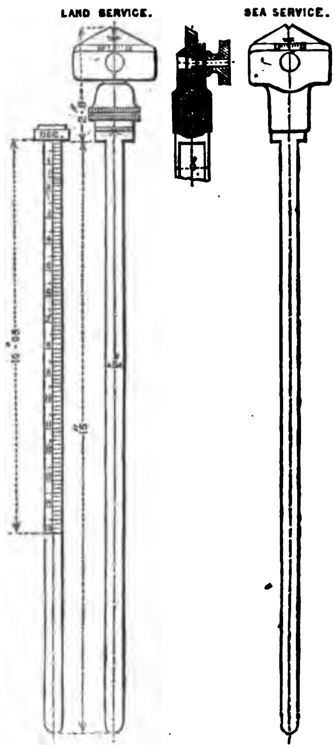
Barrel-headed sights.

In the barrel-headed sights the leaf is traversed to the right or left by means of a screw worked by milled-headed thumbscrews at each end of the barrel head. This screw is of such a pitch that the thumbscrews make a complete revolution in traversing the leaf 10′, and the circumference being graduated from 1 to 10 any required number of minutes can be accurately given.

There are arrows on the barrel head showing the direction in which the screw is to be turned to give right or left deflection, and the deflection scale is graduated to a half a degree (30′) on each side in three divisions of 10′ each.

SLIDING-LEAF SIGHTS.

Scale $2\frac{1}{2}'' = 1$ foot.



Sliding-leaf sights.

In the present pattern the leaf is traversed by hand and clamped in the required position by a milled-headed screw on the front or muzzle side, and, though not quite so accurately adjustable as the old pattern, it has the advantages of lightness (compared with the bar) and cheapness, and is not so liable to become stiff in working. Moreover, the tangent scales being now set at an angle to the left to compensate for the lateral deviation caused by the right-handed rifling, it is only necessary to use the deflection scale in order to allow for wind or other causes of irregularity.

Graduation of bars.

The steel tangent bars are graduated on one of their narrow sides in degrees, and on the other in yards; those for the 64-pr. (wedge) 7-inch guns of 82 cwt. and 40-pr. screw guns have also a graduation on one of their flat sides (right), showing the number of tenths of fuze corresponding to the range scale. Each degree is divided into six divisions of 10 minutes each.

Land Service sights have under the cross-head an "elevating nut," the circumference of which is graduated from 1 to 10, so that by turning it until the required number is in line with a *fleur-de-lis* marked on the sight any number of minutes elevation less than 10 can be obtained. This was considered unnecessary by the naval authorities, "as the "tangent bar can be set to eye to within 2′ or 3′, which corresponds "to about 16 or 24 yards of range—an insignificant quantity when "compared with unavoidable errors arising from other sources." But in all other respects the L.S. and S.S. tangent sights are identical. **Elevating nut for land service only.**

The tangent sights for the 7-inch gun of 72 cwt. and the 12-pr. are exceptional, as they have hexagonal gun-metal bars instead of the flat steel bars used with all the other natures. The reason of this difference is, that these guns were the first B.L. guns introduced, and it was then thought that the hexagonal gun-metal bars would answer best; and afterwards, when the flat steel bars were preferred, it was not considered worth while to alter the few 7-inch guns of 72 cwt. in the service, whilst the cost and trouble of altering the numerous 12-prs. would be considerable. **7-inch, 72 and 12-pr. exceptional.**

In all natures, except the 7-inch (breech-screw) 64-pr. and 40-pr. (wedge) guns, the tangent sights work in a ring screwed on to the breech of the gun at 2° 16′—the angle in B.L. guns at which it is necessary to incline them to the left, so as to compensate for the lateral deviation caused by the right-handed rifling. **Tangent sight rings.**

In the 7-inch (breech-screw) 64-pr. and 40-pr. (wedge) holes are drilled in the gun itself at that angle, and sockets are fixed in them for the tangent sights; the thickness of metal in the other natures is not sufficient to allow of this method being adopted. **Sockets in some guns.**

The angle at which the tangent sights of rifled guns is inclined to the left is called the "permanent angle of deflection," and when a gun is about to be introduced into the service, this angle is calculated from actual practice at Shoeburyness with the specimen gun sent there for trial of range and accuracy. The gun is either sighted perpendicularly or in some cases it is not sighted at all, elevation being given by temporary means. **"Permanent angle of deflection."**

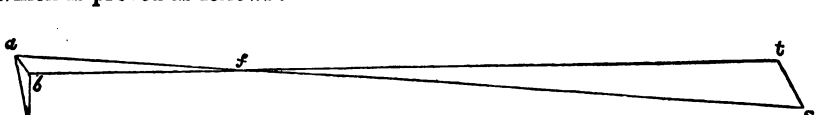
A still day being chosen, a number of rounds are fired with various elevations, generally a series of 10 rounds at 1°, 3°, 5°, &c., and the angle is calculated, by the subjoined formula, for each elevation.

The mean of the angles so obtained is adopted as the permanent angle of deflection. **Method of ascertaining the angle of deflection.**

The formula used for determining the angle for each range is

$$\tan\theta = \frac{\text{deflection}}{\text{range}} \times \text{cosec elevation,*}$$

which is proved as follows:—



Let *bc* represent a perpendicular tangent sight, and *f* the foresight of the gun, then *bft* represents the line of sight, the gun being laid on the target *t*, with the angle of elevation *bfc*=*e*.

* This neat formula is due to Major R. W. Haig, R.A. The figure is drawn out of proportion in order that it may be a convenient size.

Suppose s to be the point where the shot falls, then ts measured at right angles to the line of sight represents the deflection of the shot.

Join sf and produce it to a, draw ba at right angles to bt and join ac.

Now a is the point at which the head of the tangent sight should be placed, in order to compensate for the deflection ts, and $acb=\theta$ is the *angle of deflection* required.

Let the range $ft=r$ and the deflection $ts=d$.

Now by similar triangles

$$\frac{ab}{bf}=\frac{st}{tf}=\frac{d}{r}$$

But $ab=bc \tan \theta$ (abc being a right angle),

And $bf=bc \operatorname{cosec} e$ (bcf being a right angle),

$$\text{Therefore, } \frac{d}{r}=\frac{bc \tan \theta}{bc \operatorname{cosec} e}$$

$$\text{Or} \qquad \tan \theta=\frac{d}{r} \operatorname{cosec} e.$$

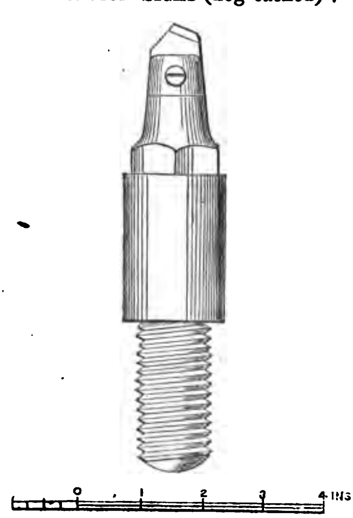
Arrangements for clamping tangent sights. In the 20-pr. and lower natures (*i.e.* all the portable guns) the tangent sights are clamped at the proper elevation by means of a copper set-screw, right and left handed, passing through a boss in the ring, and attached permanently to the gun by short chains. The 64-pr. wedge gun has similar set-screws, but there are no chains, as the shape of the breech prevents them from being removed.

The 7-inch gun of 72 cwt. has a gun-metal clamping screw working in a projecting boss on the tangent sight socket, both clamping screw and socket being removeable from the gun for transport, as they project above the metal of the gun and are therefore liable to injury.

In all the other natures the sight is fixed by a moveable clamp (see page 69) which permits the sight to be removed from the socket and taken to the light for adjustment, during the operation of loading a rather useful arrangement between decks or in casemates. Spare tangent sights are issued complete for each nature, so that when one is damaged on service it can simply be replaced by a new one without further trouble.

Screw Trunnion Sight (hog backed) 7″, 72 cwt.

Breech. Muzzle.



There are two kinds of trunnion sights, viz., the screw pattern and the drop pattern. The former is used with field guns, *i.e.*, 12-prs., 9-prs., and 6-prs.;* they are screwed into the gun so that they may not be shaken about and loosened when moving over rough ground. The latter is used with the higher or comparatively stationary natures. It consists of a pillar, collar, and socket of gun-metal, a leaf of steel, and screw for fixing the leaf. The socket is permanently fixed in the gun, and the pillar and collar each lock into it with a bayonet joint, so that when once the sight is in its true position, it cannot be removed without first raising the collar and turning the pillar round a quarter of a circle. **Trunnion sights. Screw pattern. Drop pattern.**

The advantages of the drop over the screw pattern are that the former can be easily removed for transit and afterwards replaced in its true position without any trouble; spare sights can also be carried ready to be placed in the gun without requiring any adjustment. (See page 82.)

Spare drop trunnion sights are issued complete, and with the leaf finished, so that a new one may be put into the gun when required; but screw trunnion sights must be issued with rough leaves; hence the field guns are the only ones with which the process of adjustment has to be performed on service. **Adjustment.**

N.B.—Both tangent and trunnion sights are marked for the nature of gun to which they belong, and all tangent sights (both L.S. and S.S.) are interchangeable for the same natures except between the L.S. and S.S. 20-prs. The fore-sights for the wedge gun are marked "trunnion" and "centre fore" respectively, as they are not interchangeable.

Process of Sighting.—Tangent Sight Rings.

These rings are made of wrought-iron, great care and particular attention being paid to the perfect parallelism of the sockets. The first thing in the process of sighting is to screw on the ring to the gun at the required angle of deflection. For this purpose the screw for the tangent sight ring is cut on the extreme breech end of the gun in a screw-cutting lathe. It is essential that the threads should be so cut that when the ring is screwed home tight its sockets should be at an angle of 2° 16′ to the vertical plane. When the screw is cut, the gun is levelled across the trunnions in the machine. and the tangent sight ring being screwed on, a bar representing the tangent scale is dropped into one of its sockets, and an angular level, with its arms at an angle of 92° 16′, is held against its left side; the ring is then struck round with a mallet until it is perfectly true. The operation is performed while in the machine, in order that the screw on the gun may be rectified if found incorrect. This setting is again examined and verified, after which the ring is plugged so as to make it immoveable. This is done by drilling a hole through the thread and driving in a pin or plug; the ring thus becomes a permanent part of the gun. **Sighting. Screwing on at 2° 16′.**

Sockets.

These are of gun-metal and cast hollow, and fixed into slots bored for them in the breech of the gun at the required angle. They have a shank and dovetail. The tangent sight is let into the hollow shank, and the dovetail prevents the socket shifting round in the gun. **Fixing sockets in 7-inch and wedge guns.**

When the sockets are fixed in their places they are secured by a small screw, so that they shall not be shaken out by the discharge, but the screw is removeable. The sockets of 7-inch 72 cwt. guns are taken out when the gun is shifted, as they project above the metal of the gun (see page 71).

* The 7-inch 72 cwt. gun retains the screw trunnion sight for the same reason that it uses the hexagonal gun-metal tangent sight.

*Boring for Trunnion Sights.**

Great care is taken to have the trunnion sight holes in their proper position. Their centres on each side of the gun must be exactly at the same distance from a vertical plane passing through the axis, as the notches of the tangent sight are when that sight is at zero. This is effected by means of silk cords stretched from the sighting plates at breech and muzzle, as described in the process of sighting Rifled M.L. guns (see page 114). The holes must also be at the correct longitudinal distance with reference to the radius of the gun. They are drilled by a radial drilling machine.

In guns using the drop sight the socket or bush is fixed at the bottom of the hole, so that either trunnion sight will suit both sides of the gun.

Guns with the screw sight have a thread tapped at the bottom of the hole by means of a "guide nut" (the tap passing through it), in such manner that when the sight is screwed in, the leaf will be parallel to the axis of the bore.

Adjusting Trunnion Sights.

Adjusting the trunnion sights for the first time, or on service.

A set of sighting instruments for a B.L. gun consists of:—

1 Breech plate.
1 Muzzle plate.
1 Breech clamp.
1 Muzzle clamp.
1 Tightening rod (in two or three pieces).
2 Screwed handles.

For this process of sighting the gun is carefully levelled across the trunnions.

(1.) The plates fitted to the breech and muzzle, being held by the tightening rod which passes through the bore, are secured by the clamps and handles. The plates are so made, that when they have been levelled with the gun four lines can be marked on the face and breech, representing the vertical and horizontal axis of the bore. *These lines are to enable the gun to be sighted in future without the trouble of levelling or even dismounting the gun,* by setting the plates accordingly. On the upper edges of the breech and muzzle plates there are small notches cut at equal distances from the centre, so that if a silk line be stretched from the notch on either side of the breech to the corresponding one at the muzzle, that line will be parallel to the axis of the piece.

(2.) The tangent sight is dropped into the socket, and the trunnion sight with a rough leaf fixed in its proper place.

(3.) The silk line between the muzzle and breech notches is stretched very tightly, and should pass over the centre of the notch on the tangent sight.

(4.) The leaf is filed down to the right height, *i.e.*, the level of the silk line. In doing this it is usual to raise the silk both at breech and

* For table of radii, &c., see page 68.

muzzle by the thickness of a piece of paper, when it should just clear the leaf, and when the paper is removed it should touch the same.

(5.) The position for the apex on the trunnion sight is then ascertained by the length of radius for each nature of gun (see table, page 68), measured from the notch on the tangent sight. The apex is not in the axis line of the socket, except in 6-prs. and 9-prs.

In 12-prs. it is	0″·05 to the rear.
„ 20-prs. }	
„ 40-prs. }	0″·2 „
„ 7-inch }	
„ 64-prs. (wedge)	0″·1 „

(6.) Remove the sight from the gun, place it in a vice, and file down the front and back slopes. The slopes should be sufficient to form a point when the gun is at its highest elevation.

(7.) Replace the sight in the gun and file down the lateral slopes, so that a true edge is obtained under the silk line, care being taken that the top of the leaf is not made too sharp, as it would be liable to injury. In the case of a screw trunnion sight, a curved line is marked by a scriber, to show the position of the metal surface of the trunnion when the sight is screwed home.

Note.—The above operations are performed on both sides of the gun.

(8.) The trunnion sight is again removed and the back slope is roughed, so that in laying a gun there may not be too bright a reflection presented to the eye; it is marked for the particular gun to which it has been fitted; for the screw pattern, in addition, the curved line is filed to make it more visible, and it is marked R or L, according to the side of the gun in which it has been fitted, and is therefore not interchangeable, after it has been fitted, like the drop pattern.

Readjusting Trunnion Sights of B.L. Field Guns on Service without the aid of Sighting Instruments.

As sighting instruments are no longer issued to Batteries and only to some stations, it may be found necessary to adjust damaged trunnion sights on service without them, this may be done in the following manner, viz., by making wooden copies of the proper instruments.

The requisite materials are:— Requisite materials.

Two blocks or discs of wood to fit into breech and muzzle.

Two rectangular pieces of wood long enough to project beyond the tangent sights on each side, and of such width that the upper edge shall be level with the top of the *right* tangent sight, when the lower edge coincides with the line of horizontal axis marked on the breech and muzzle.

Four screws to fasten these pieces together.

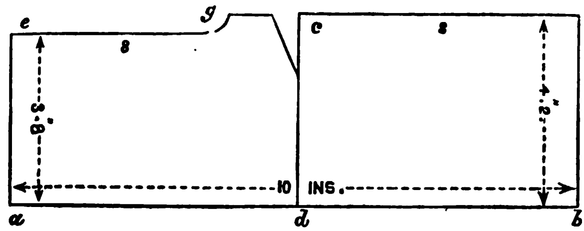
Two silk or fine thread lines.

The object of the following operation is to obtain a line on each side of the gun through the tangent sight notch parallel to the axis of the bore. Operation.

(1.) Remove the breech-screw and fasten the breech and muzzle discs in the gun securely by wedges.

(2.) Fasten the two rectangular pieces together and plane their lower edges *a b* (see Fig.) level, treating them as one piece. Then square up a

FOR 12-PR., BREECH-SCREW GUN.



line *c d* at the centre of each at right angles to *a b*, and cut away the wood on one side of *c*, in order that *c d* may be brought against the vertical line on the face of the breech or muzzle.

(3.) Now bring *a b* against the horizontal line, and *c d* the vertical line marked on the breech, and fasten the boards by two screws to the disc in the breech of the gun.

(4.) Cut away the top until it is level with the *bottom* of the notch of the tangent sight on each side, the left side *e g* will require to be cut away more than the right.

(5.) Then with a rule brought by eye parallel to the axis of the gun, mark lines *s s* on the top of the boards opposite the tangent sight notches on each side; this can be done sufficiently accurately by eye, as any error is corrected in the after operations.

(6.) Remove the boards from the gun and separate them, fastening one at the breech and the other at the muzzle, taking care to adjust them to the horizontal and vertical lines on the gun.

(7.) Stretch silk lines on each side of the gun from the marks *s s* on the breech and muzzle board; they should pass exactly through the bottom of the notch of the tangent sights. If they do not they must be moved to the right or left until they do, but care must be taken always *to move the line the same amount both at breech and muzzle*, so as to keep it parallel to its original position. These lines are parallel to the axis of the gun, and the trunnion sight leaf can be filed and adjusted as detailed at page 74.

These wooden sighting blocks will serve for any gun of the same nature, after having once been accurately fitted.

DIMENSIONS, RIFLING, SERVICE, &c. of BREECH-LOADING GUNS. (*Vide* Chapter VI., p. 78.)

Nature, Weight, and Service.	Calibre.	Barrel, Total.	Length.					Diameter.		Rifling (the many-grooved system).					Preponderance of sealed pattern.	Remarks.
			Powder Chamber.	Shot Chamber.*	Nominal.†	From muzzle to axis of trunnion.	From axis of trunnion to breech.	Greatest over charge.	Muzzle.	Twist.	Grooves. Number.	Grooves. Depth.	Grooves. Width.	Width of lands.		
Breech-Screw.	"	"	"	"	"	"	"	"	"			"	"	"	cwt. qrs. lbs.	
7-inch of **82** cwt. L.S. & S.S.	**7**	99·5	16·0	9·0	**120**	74·7	45·3	27·7	13	1 turn in 37 cals.	76	·06	·166	·1233	6 3 16	The S.S. 7″ B.L. guns are gradually being replaced by 7″ rifled M.L. guns of 6½ tons and 90 cwt.
7-inch of **72** cwt. L.S.	**7**	97·5	14·25	9·0	**118**	71·25	46·75	24·7	13	Do.	76	·06	·166	·1233	7 3 27	
40-pr. of **35** cwt. L.S. & S.S.	**4·75**	106·375	13·5	7·0	**121**	73·875	47·125	16·4	7·75	1 turn in 36½ cals.	56	·06	·166	·1	4 3 0	
40-pr. of **32** cwt. L.S. & S.S.	**4·75**	106·375	13·5	7·0	**120**	73·875	46·125	16·438	7·75	Do.	56	·06	·166	·1	5 1 19	
20-pr. of **16** cwt. L.S.	**3·75**	84·0	12·0	6·0	**96**	59·375	36·625	12·5	6·0	1 turn in 38 cals.	44	·06	·166	·1	2 0 11	
20-pr. of **15** cwt. S.S.	**3·75**	54·125	11·0	6·0	**66·125**	39·5	26·625	13·5	6·25	Do.	44	·06	·166	·1	1 2 0	
20-pr. of **13** cwt. (boat) S.S.	**3·75**	54·125	11·0	6·0	**66·125**	40·0	26·125	12·5	6·0	Do.	44	·06	·166	·1	1 1 24	
12-pr. of **8** cwt. L.S. & S.S.	**3**	61·375	8·5	3·0	**72**	38·75	33·25	9·75	5·75	Do.	38	·045	·148	·1	1 3 3	
9-pr. of **6** cwt. L.S. & S.S.	**3**	52·5	7·0	3·0	**62**	36·5	25·5	9·6	5·3	Do.	38	·045	·148	·1	0 2 26	
6-pr. of **3** cwt. L.S. & S.S.	**2·5**	53·0	7·0	2·5	**60·125**	37·0	23·125	7·0	3·75	1 turn in 30 cals.	32	·045	·148	·1	0 1 27	
Wedge.																
64-pr. of **61** cwt. L.S.	**6·4**	92·0	14·5	8·0	**110·0**	68·5	41·5	24·2	14·1	1 turn in 40 cals.	70	·06	·166	·1212	5 2 0	Takes the 40-pr. breech-screw gun ammunition.
40-pr. of **32** cwt. S.S.	**4·75**	83·5	13·5	7·0	**98·0**	63·8	34·2	19·2	7·75	1 turn in 36½ cals.	56	·06	·166	·1	2 3 5	

* Exclusive of slopes in front and rear of shot.

† *i.e.* from face of muzzle to extreme end of breech, exclusive of breech-screw.

CHAPTER VI.

RIFLED B.L. GUNS IN THE SERVICE, AND THEIR MISCELLANEOUS STORES.

Table of dimensions, rifling, &c.—Breech-screw Guns in Service.—Wedge Guns.—7-inch of 72 cwt.—7-inch of 82 cwt.—40-pr., 32 cwt.—40-pr., 35 cwt.—20-pr., 16 cwt.—20-pr., 15 cwt.—20-pr., 13 cwt.—12-pr., 8 cwt.—9-pr., 6 cwt.—6-pr., 3 cwt.—64-pr. (wedge), 61 cwt.—40-pr. (wedge), 32 cwt.—*Table of B.L. Fittings.*—Bearers, Shot.—Bits, Vent.—Bushes.—Clamps.—Collars, Leather, Breech-screws.—Covers, Metal, for Vents.—Crutches.—Extractors, Tin Cup.—Eyes, Elevating.—Guide-Plates.—Implements, Facing, Table of.—Instruments, taking impressions of Bores of Guns.—Instruments, Sighting.—Irons, Priming.—Levers.—Machine, Hand Rifling.—Patch, Metal, Elevating.—Pins, Friction Tube, &c.—Punches, Vent.—Rings, Copper, Vent-piece.—Saddles, Metal.—Scales, Wood, Side.—Screws.—Sights.—Sockets, Metal.—Stops for Breech Stopper.—Stoppers, Steel, Breech.—Straight Edge, for Testing Breech Screws, &c.—Vent-pieces.—Wedges, with Handles.—Wires, Priming.

TABLE OF DIMENSIONS, &c. (*vide* p. 77.)

SPECIALITIES OF RIFLED B.L. GUNS.

Breech-screw.

There are	two natures*	of 7-inch guns.	
„ „	two	do.	40-prs.
„ „	three	do.	20 do.
„ is	one nature		12 do.
„ „	one *	do.	9 do.
„ „	one	do.	6 do.

Wedge.

There is one nature of 64-pr., and one of 40-pr.

The § in the margin denotes the authority under which the different articles, &c. have appeared in the War Office "List of Changes."

The manufacture of these guns and their fittings has been generally described already.

§ 593. **7-inch of 72 cwt.** L.S. consists of:—
A tube or inner barrel.
Breech-piece and B tube.
Trunnion-ring, and
Four coils. (See lithograph R.G.F. No. 12.)

Recommended in 1859 (then 100-pr.), for the navy, as a broadside or pivot gun, to replace the 68-pr. smooth-bore, but it was soon discovered that owing to the gun being so light, the recoil on board ship was excessive; hence so few (76) of this weight manufactured.

§ 593. There are two classes of this gun respectively marked on the left trunnion A and B; they only differ in length of barrel and breech, A being 2″ longer in the barrel than B, and consequently 2″ shorter in the breech.

§§ 666–899. In 1863 its designation was changed to "light" 110-pr., and finally, to 7-inch of 72 cwt.

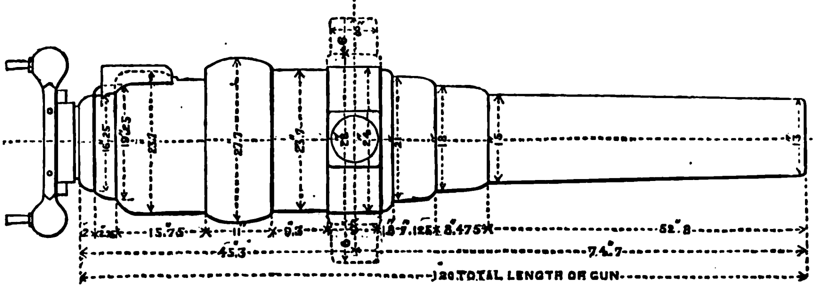
O.S.C. Proceedings, 1868. This gun is at present only used for garrison service, but it is in contemplation to adapt it for siege purposes, to be fought upon a naval carriage and slide.

* Two guns of the same calibre, but differing in *weight*.

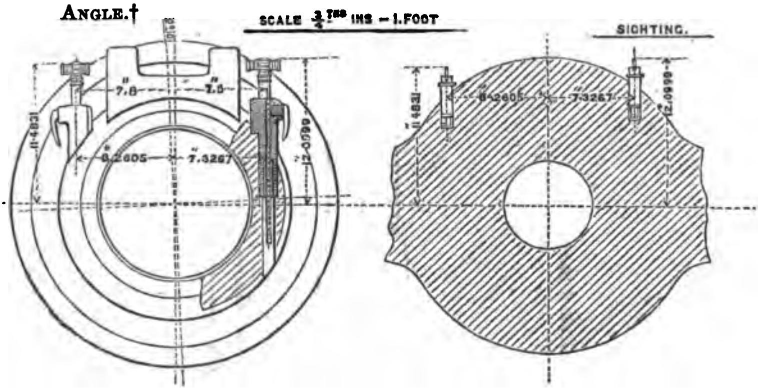
7-inch gun of 82 cwt. L.S. and S.S. consists of:— §935.

A tube.
Breech-piece and B tube.
Trunnion-ring, and
Six coils. (See No. 10.)*

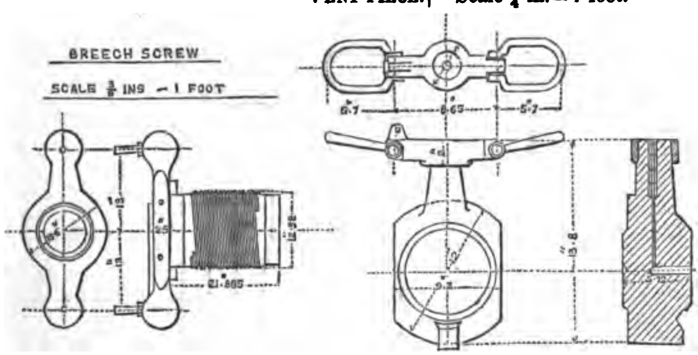
7-INCH R.B.L. GUN, 82 CWT.—Scale ⅜ in. = 1 foot.



ANGLE.†



VENT-PIECE.†—Scale ¾ in. = 1 foot.



This gun was introduced in 1861, being a stronger gun than the 7-inch of 72 cwt. It is known from the latter by having a high coil in front of the vent slot, termed a "strengthening coil," and an additional coil in front of the trunnions.

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* *i.e.* lithograph $\frac{\text{R.G.F.}}{\text{No. 10}}$. These lithographs are published by the W. O., and can be purchased at the Royal Artillery Institution by members.

† Clamping screws for tangent sights of 7″ and 40-pr. B.L. guns, and a projection on the top of 7″ vent-piece (formerly used for the detonating hammer) may still be seen at some out-stations, but they are now obsolete.

It is used both by the land and sea service ; in the former as a garrison, in the latter as a broadside or pivot gun, but it is considered not sufficiently powerful for the penetration of iron plates, and is being gradually replaced in the naval service by the rifled M.L. 7-inch guns of $6\frac{1}{2}$ tons and 90 cwts.

Report on Ordnance, 1863, p. 250.*
Report on Ordnance, 1862, p. 218.

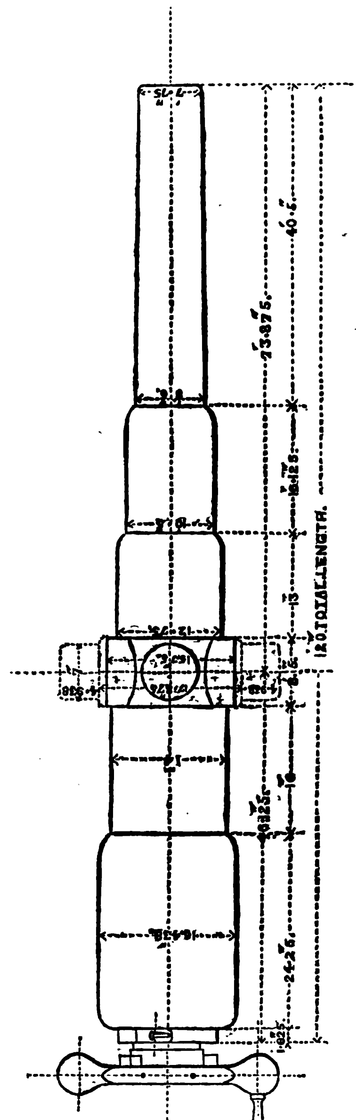
It was first termed "100-pr.," but as it transpired in 1861 that a heavier projectile could be used without causing excessive recoil, it was then called "110-pr.," and lastly, "7-inch of 82 cwt."

§§ 466–899.
§ 901.

40-pr. gun of 32 cwt. cal. 4″·75 L.S. and S.S. consists of :—

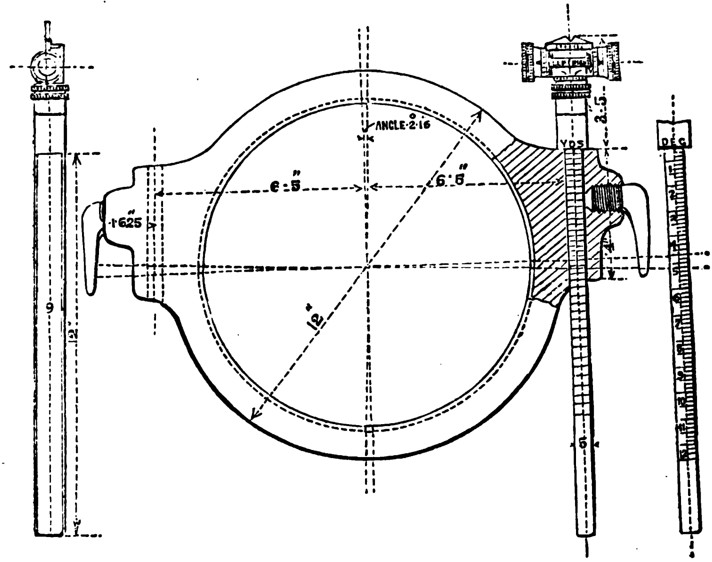
A tube.	Trunnion-ring, and
Breech-piece and B tube.	Three coils. (See No. 13.)

40-pr. R.B.L. Gun, 32 cwt.—Scale $\frac{1}{8}$ in. = 1 foot.

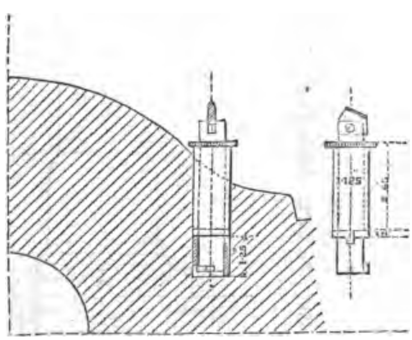


* Parliamentary blue book on ordnance expenditure.

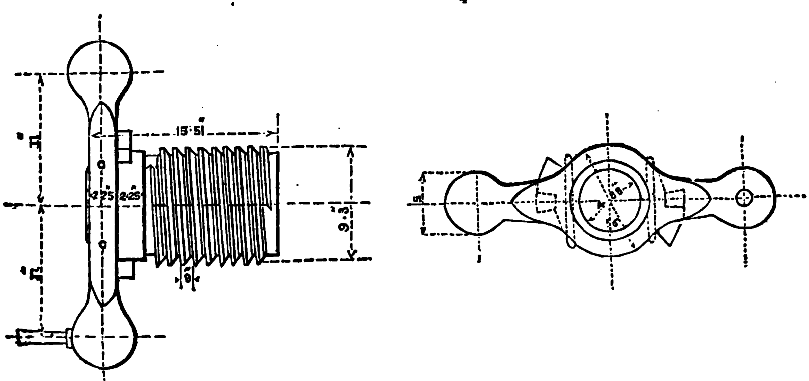
TANGENT SIGHT AND RING. Scale 2 in. = 1 foot.*



DROP TRUNNION SIGHT. Scale 2 in. = 1 foot.



BREECH-SCREW. Scale ¾ in. = 1 foot.



* See note (†) page 79.

30551. F

Report on Ordnance, 1862, p. 176.

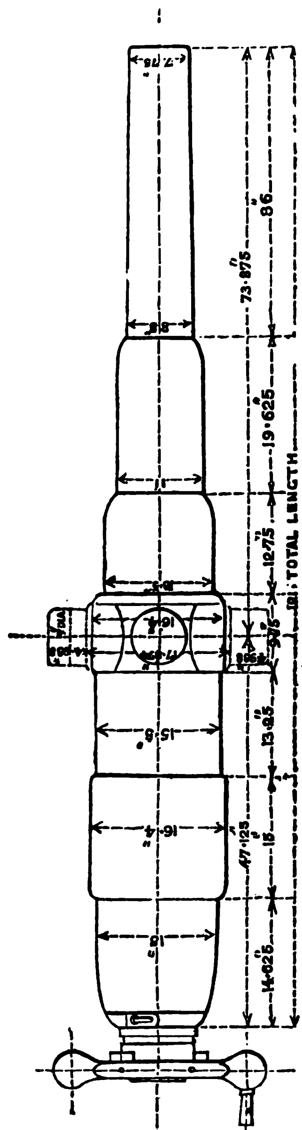
Recommended in 1859, for the navy, as a broadside or pivot gun; it is also now used by the land service for batteries of position, siege and garrison purposes.

A few of these guns have trunnions made of *cast iron*, and are known by the face of the trunnion being bored out in the centre.

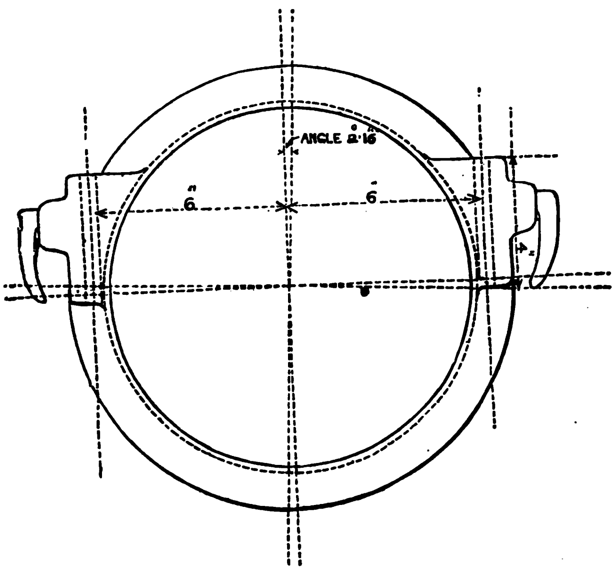
This gun is sometimes termed the O.P. (old pattern) 40-pr.

§ 902. **40-pr. gun of 35 cwt.** cal. 4″·75 L.S. and S.S. consists of the same number of parts as the 32 cwt. gun, but has a longer and a stronger breech-piece, which is unsupported behind the vent slot and rounded off. It has a raised coil in front of the vent slot, and is known as the "G" pattern. (See No. 2.)

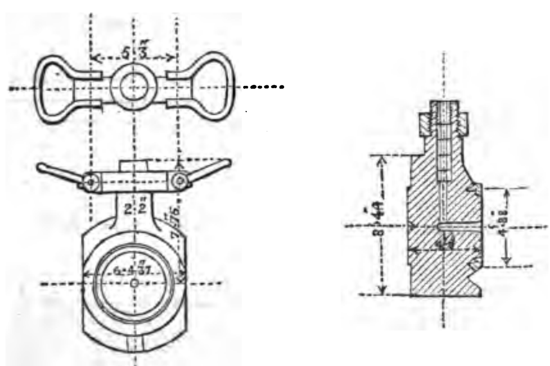
40-PR. R.B.L. GUN, 35 CWT. Scale $\frac{1}{8}$ in. = 1 foot.



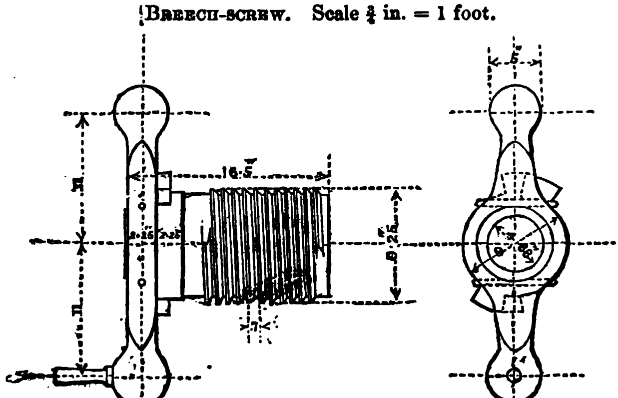
TANGENT SIGHT RING. Scale 2 in. = 1 foot.



VENT-PIECE.* Scale 1 in. = 1 foot.



BREECH-SCREW. Scale ¾ in. = 1 foot.



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* Interchangeable for both 40-prs.

Report on Ordnance, 1862, p. 218.

This pattern was introduced in 1860, more as a matter of precaution than from any symptoms of weakness in the lighter nature. It is used for the same purposes as the 32 cwt. gun, and the fittings are interchangeable with the exception of the breech-screw, which has a different shape and pitch of thread.

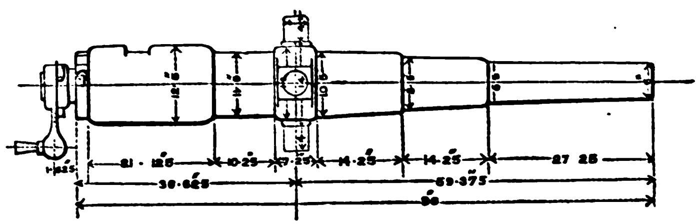
NOTE.—One of these guns, No. 363, E.O.C., at Shoeburyness, has fired to 1st June 1872, 4,493 rounds, with projectiles, and is still serviceable, and No. 54, E.O.C., has fired on board H.M.S. "Excellent" 5,615 rounds.

§ 998.

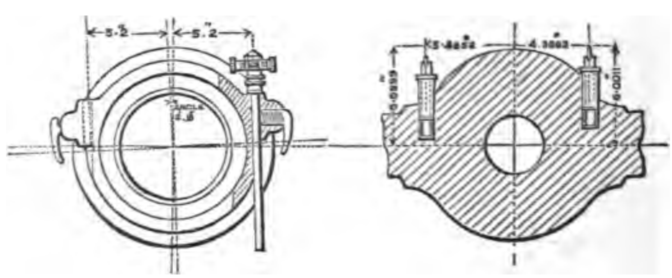
20-pr. gun of 16 cwt. cal. 3″·75 L.S. consists of:—

A tube.
Breech-piece.*
Trunnion-ring, and
Five coils. (See No. 14.)

20-PR. R.B.L. GUN OF 16 CWT. Scale ⅜ in. = 1 foot.†



TANGENT AND DROP SIGHT. Scale 1 in. = 1 foot.



Report on Ordnance, 1862, p. 177.

Recommended in 1859 (then 25-pr.) as a light gun of position, but subsequently it was resolved to use a lighter projectile; hence its alteration to 20-pr.‡

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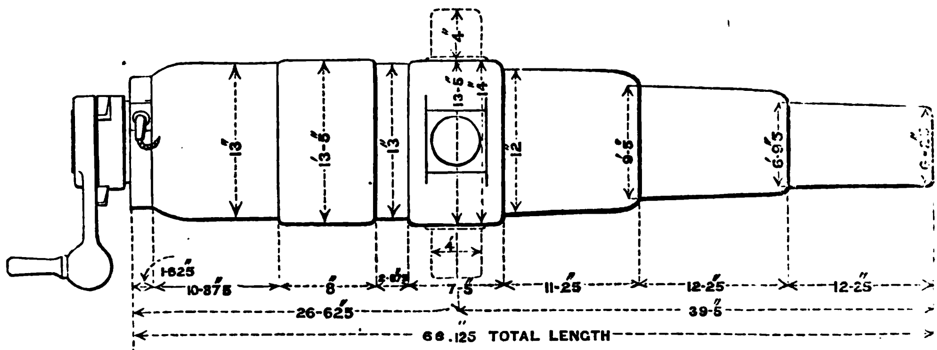
* Guns under 40-prs. have no B tubes.
† It is to be regretted that the woodcuts in this Section are not all on the same scale, but for the sake of economy the blocks prepared from time to time for the List of Changes in Ordnance, &c. have been utilized.
‡ This also applies to the other 20-prs.

20-pr. gun of 15 cwt. cal. 3″·75 S.S. consists of :— § 904.

A tube.
Breech-piece.
Trunnion-ring, and
Three coils. (See No. 15.)

20-pr. R.B.L. Gun, 15 cwt. Scale ¾ in. = 1 foot.

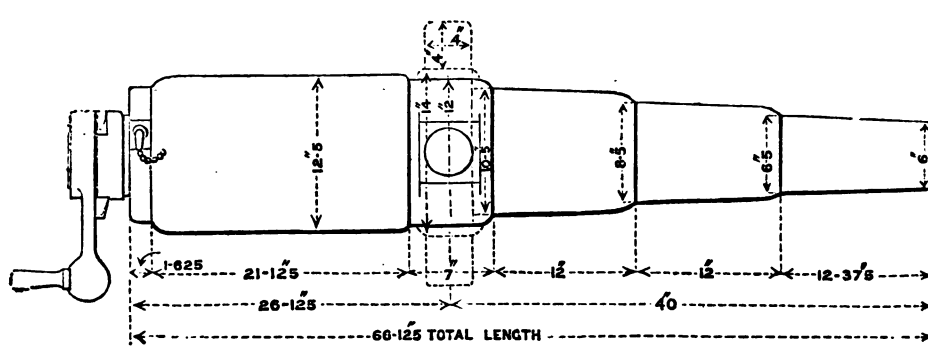


Was adopted in 1859, for the navy, as a broadside gun for ships of the sloop class, in which there is not sufficient width of beam to work the land service 20-pr. Its external appearance is entirely different from that of the land service 20-pr., as it is 2½ feet shorter, has a raised coil in front of the vent slot, and the breech-piece is unsupported in the rear. Report on Ordnance, 1862, p. 218.

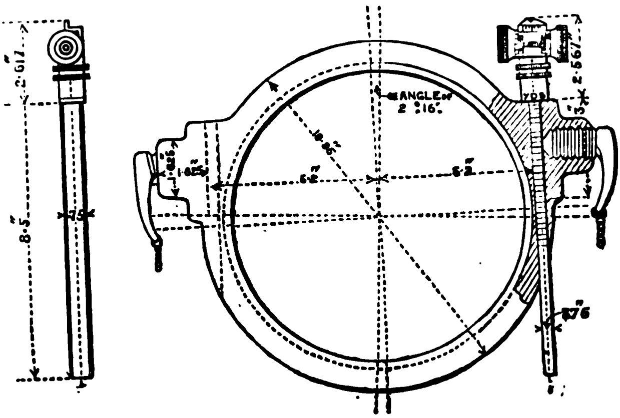
20-pr. gun of 13 cwt. cal. 3·75″ S.S. consists of :— § 903.

A tube.
Breech-piece.
Trunnion-ring, and
Four coils. (See No. 16.)

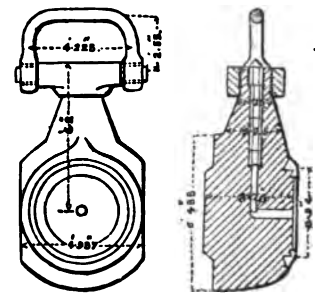
20-pr. R.B.L. Gun, 13 cwt. Scale ¾ in. = 1 foot.



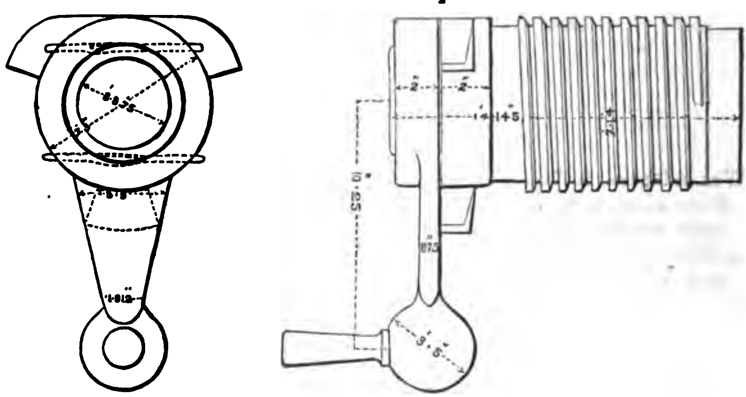
TANGENT SIGHT AND RING. Scale 2 in. = 1 foot.



VENT-PIECE.*



BREECH-SCREW.* Scale 1½ in. = 1 foot.



Report on Ordnance, 1862, p. 218; 1863, p. 155. Recommended in 1859, for the navy, as a boat or field marine gun, and is termed the "pinnace gun." This and the 15 cwt. gun are much alike in appearance, but differ in their construction, the heavier pattern being stronger in every respect; neither of them shoot as well as the L.S. 20-pr.

§ 1986. It is now used on the upper decks of iron-clad ships for action at close quarters to repulse boarders, and is mounted on a carriage which allows 20° elevation or 30° depression. When so used it is fitted on the right side with a gun-metal elevating plate, similar to that used with heavy guns.

A large number of the S.S. 20-prs. have lately been returned into store.

§§ 939 and 829. **12-pr. gun of 8 cwt.** cal. 3″ L.S. and S.S., and consists of :—

A tube.
Breech-piece.
Trunnion-ring, and
Three coils. (See No. 7.)

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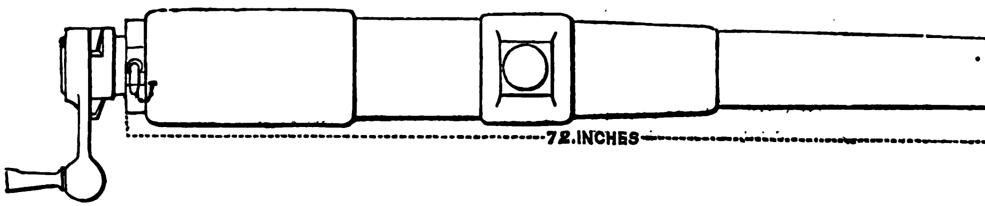
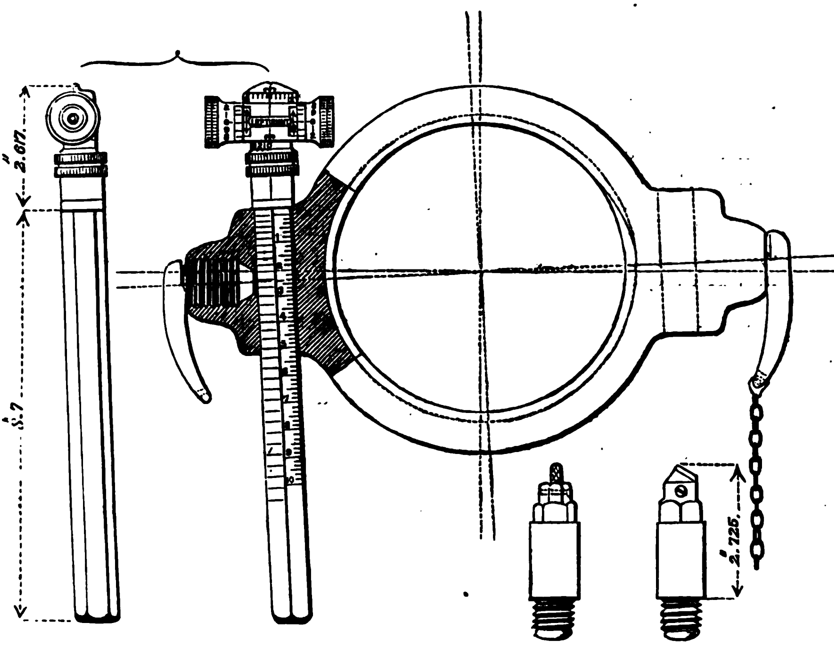
* Interchangeable for all 20-prs.

12-pr. R.B.L. Gun, 8 cwt. Scale ¾ in. = 1 foot.

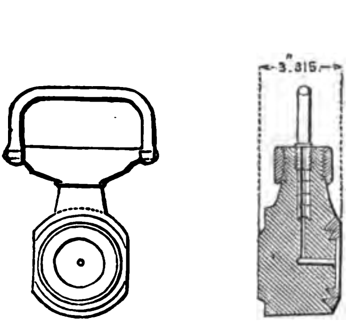


Tangent Sight and Ring. Scale 3 ins. = 1 foot.

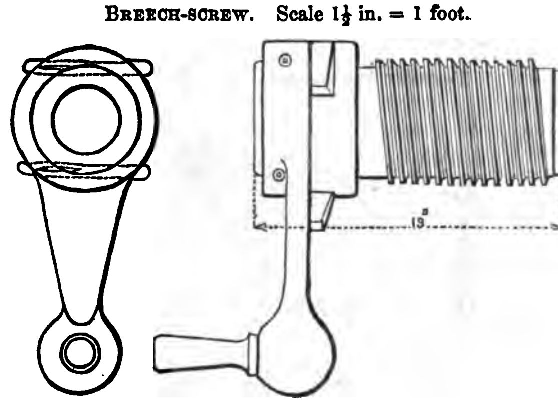


Screw-sight.

Vent-piece. Scale 1½ in. = 1 foot.



Breech-screw. Scale 1½ in. = 1 foot.



This was recommended in 1858, for the land service, as a field battery gun, and subsequently adopted by the navy as a boat or field marine gun; but the naval pattern was 12 inches shorter, and without the grip at the muzzle.

Report on Ordnance, 1862, p. 156.
§ 401.

§ 829. In 1863 an universal pattern was introduced for both services, the land service pattern being altered and improved for the purpose, as
§ 939. follows :—
§ 826. (1.) A length of 12 inches was cut off the muzzle, thus doing away with the grip, and bringing the gun to the length of the sea service.

(2.) The short coil in front of the trunnion was replaced by a longer one, which strengthened the gun in that part, and reduced the excessive preponderance consequent on the foot being cut off the muzzle.

(3.) The vent slot was widened (at its rear part) to take a thicker vent-piece. This caused a portion of the breech-screw thread to project behind; it is protected by a leather collar, which can be pared round according as the breech-screw face wears on service.

There is a peculiarity in the construction of this gun which does not exist in any other breech-loader except the 9-pr., viz., the A tube being thinner where the breech-piece covers it than in the remaining part which extends to the muzzle.

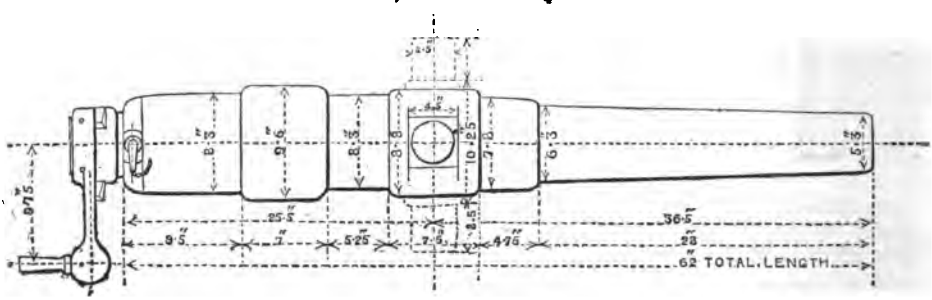
The calibre of the 9-pr. being the same as this gun it can, on an emergency, use the ammunition of the 9-pr. gun, but not *vice versâ*, the 12-pr. ammunition being longer than the 9-pr.

NOTE.—No. 7, R.G.F., at Shoeburyness, has fired up to 1st June 1872, 5,083 rounds with projectiles. After firing 4,417 rounds it received a new A tube, and is now serviceable.

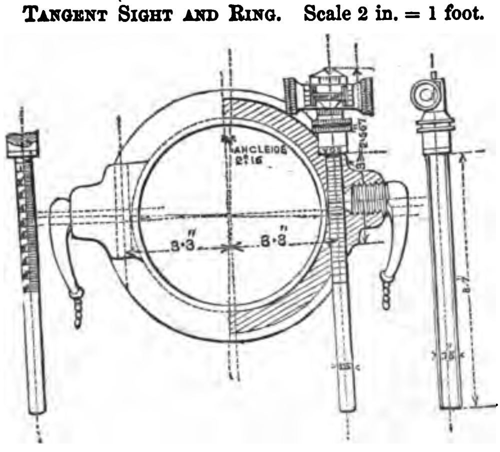
§ 905. **9-pr. gun of 6 cwt.** cal. 3″ L.S. and S.S. consists of :—

A tube.
Breech-piece.
Trunnion-ring, and
Three coils. (See No. 6.)

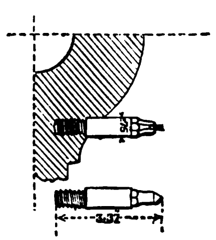
9-PR. R.B.L. GUN, 6 CWT. Scale ¾ in. = 1 foot.



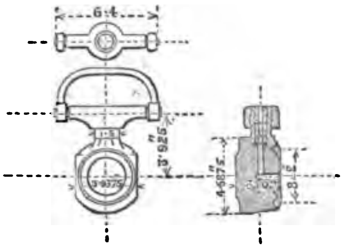
TANGENT SIGHT AND RING. Scale 2 in. = 1 foot.



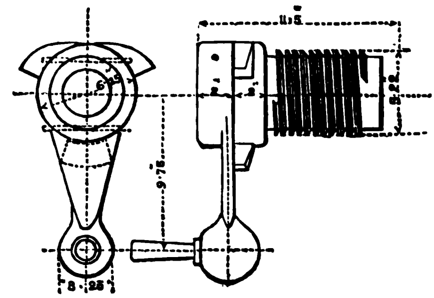
SCREW SIGHT.
Scale 2 in. = 1 foot.



Vent-piece. Scale 1 in. = 1 foot.



Breech-screw. Scale 1 in. = 1 foot.

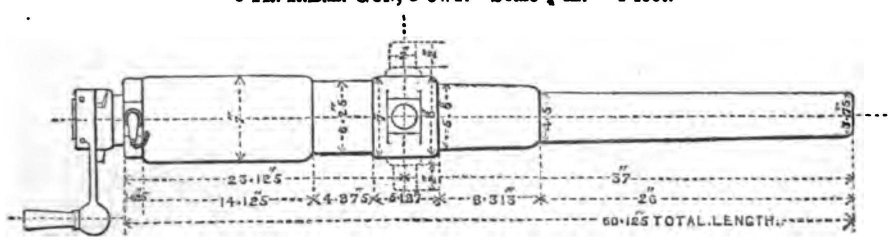


Introduced in 1862, for the Horse Artillery, and is the latest pattern of all the breech-loading breech-screw guns. The navy use it as a boat or field marine gun. It has the same peculiarity in the A tube as the 12-pr. § 474. § 529.

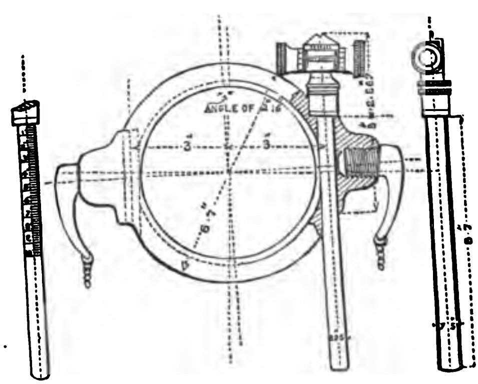
6-pr. gun of 3 cwt. cal. 2·5″ L.S. and S.S. consists of:— § 906.

A tube.
Breech-piece.
Trunnion-ring, and
One coil. (See No. 5.)

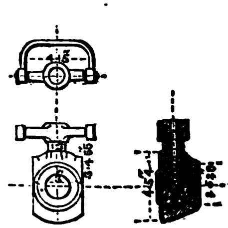
6-pr. R.B.L. Gun, 3 cwt. Scale ¾ in. = 1 foot.



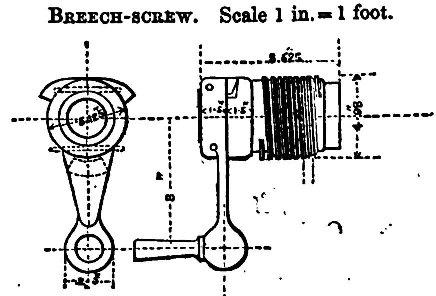
Tangent Sight and Ring. Scale 2 in. = 1 foot.



Vent-piece.
Scale 1 in. = 1 foot.



Breech-screw. Scale 1 in. = 1 foot.



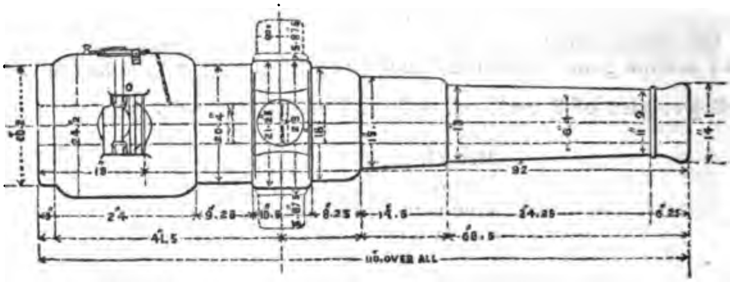
Report on Ordnance, 1862, p. 156.

Recommended in 1858, for mountain service, but, as it was considered too great a load for a mule, its use is restricted to colonial batteries; the navy employ it as a boat or field marine gun.

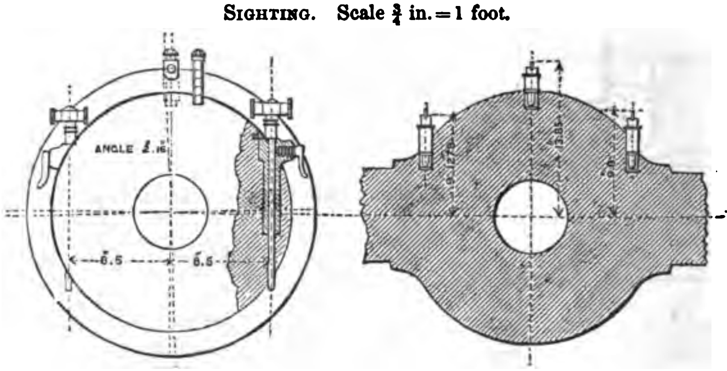
§ 997.

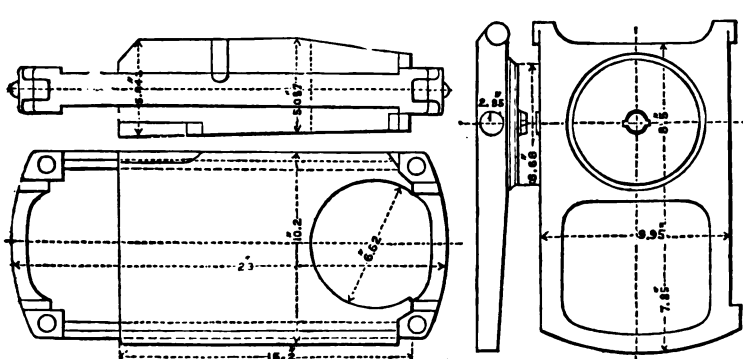
64-pr. (wedge) gun of 61 cwt. cal. 6·4″ L.S. consists of :—
A tube.
Breech-piece and B tube.
Trunnion-ring, and
Four coils. (See No. 20.)

64-PR. R.B.L. (WEDGE) GUN, 61 CWT. Scale ⅜ in. = 1 foot.



SIGHTING. Scale ¾ in. = 1 foot.





Report on Ordnance, 1863.

Owing to the dissatisfaction evinced by many naval officers with respect to the system of closing the breech, &c. in the heavy breech-

screw guns, the wedge gun was adopted for S.S. in 1864;* but while experiments were being carried on with this system of loading, the Admiralty requested that four 64-pr. blocks (then called 70-prs.) should be completed as muzzle-loaders with a bore suited to use 32-pr. S.B. *spherical* prejectiles in case of an emergency. Subsequently it was decided to complete all the remaining blocks into 64-pr. muzzle-loaders on the shunt system of rifling; hence so few of this nature manufactured, and the exterior similarity in the two guns, M.L. and B.L. (See page 60.)

O.S.C. Proceedings, 1863, p. 236.
O.S.C. Proceedings, 1864, p. 98.

So few being made the question arose as to the advisability of issuing these wedge guns to ships, seeing it would necessitate a reserve of special ammunition being stored at all outports; consequently it was decided ***not to issue them to the navy***, but to use them only for land service, as siege or garrison guns.

O.S.C. Proceedings, 1864, p. 253.
O.S.C. Proceedings, 1865, p. 30.

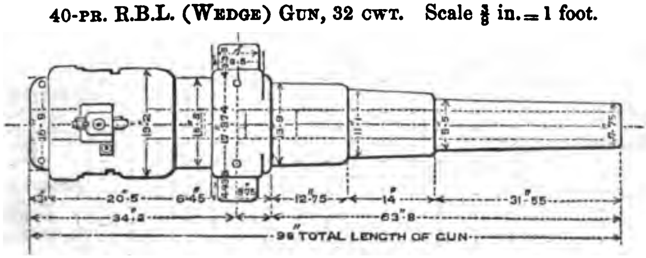
It is the only rifled B.L. gun that has a "swell" at the muzzle, which consists of a small coil plugged on, and intended for the navy as a means of "housing" the gun.

§§ 1155–1247.

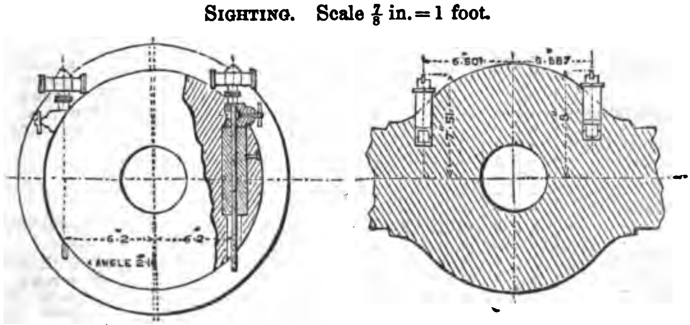
40-pr. (wedge) gun of 32 cwt. cal. 4·75″ S.S. consists of:— § 1182.

A tube.
Breech-piece.
Trunnion-ring, and
Four coils. (See No. 19.)

40-PR. R.B.L. (WEDGE) GUN, 32 CWT. Scale ⅜ in. = 1 foot.



SIGHTING. Scale ⅞ in. = 1 foot.



The 40-pr. breech-screw gun being found too long for narrow-waisted vessels, this wedge gun was introduced for that class of shipping in 1860. Only 52, however, have been made, and none are actually in use at the present time.

O.S.C. Proceedings, 1864, p. 27.

The ammunition is common to both breech-screw and wedge 40-pr. guns.

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* The wedge system was proposed by Sir W. Armstrong in 1861. See Ordnance Select Committee Proceedings, 1863, p. 308.

Nomenclature of all Fittings and Stores made in the Royal Gun Factories for the Rifled B.L. Guns.	7-inch Gun. 82 cwt. Sea Service.	7-inch Gun. 82 cwt. Land Service.	7-inch Gun. 72 cwt. Land Service.	40-pr. Gun. Sea Service.	40-pr. Gun. Land Service.	20-pr. Gun. Sea Service.	20-pr. Gun. Land Service.	12-pr. Gun. Sea Service.	12-pr. Gun. Land Service.	9-pr. Gun. Sea Service.	9-pr. Gun. Land Service.	6-pr. Gun. Sea Service.	6-pr. Gun. Land Service.	64-pr. Wedge L.S.	40-pr. Wedge S.S.	Remarks.
Bearers, shot*	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	Issued in certain proportions as required.
Bits, vent, Armstrong*	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	
Bits, vent, sea service	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	
Bushes, breech, iron, thick	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	
Bushes, breech, iron, thin	1	1	1	–	–	–	–	–	–	–	–	–	–	–	–	
Bushes, breech, copper	–	–	–	1	1	1	1	1	1	1	1	1	1	–	–	
Bushes, copper, vent-piece, sets	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	
Clamps, moveable, for tangent sights	2	2	–	2	2	–	–	–	–	–	–	–	–	–	2	
Collars, leather, for breech-screw	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	
Covers, metal, for vent	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	
Crutches, iron	–	–	–	1	–	1	–	1	–	1	–	1	–	–	–	
Extractors, tin-cup, L.S.	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	
Extractors, tin-cup, S.S. with lever, lifting joint.	1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
Eyes, elevating	–	–	–	–	–	–	1	–	1	–	1	–	1	–	–	
Guide-plates*	1	–	–	1	–	1	–	1	–	1	–	1	–	–	1	
Implements, facing, set	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	See page 98.
Instruments, taking impressions of bore of guns. No. 1	1	1	1	1	1	–	–	–	–	–	–	–	–	1	1	
Instruments, taking impressions of bore of guns. No. 2	–	–	–	–	–	1	1	1	1	1	1	1	1	–	–	
Instruments, sighting, set	1	1	1	1	1	1	1	1	1	1	1	1	1	1	–	
Irons, priming	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	
Levers, breech-screw	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	
Levers, iron, releasing vent-piece*	1	1	1	–	–	–	–	–	–	–	1	–	–	–	–	
Machines, hand rifling	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Patches, metal elevating	–	–	–	–	–	–	–	1	–	1	–	1	–	–	–	
Pins, friction tube*	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1	
Pins, keep, lever	2	2	2	2	2	2	2	2	2	2	2	2	2	–	–	
Pins, keep, pivot, elevating	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	For 20-pr. 13 cwt. guns when used on upper decks.
Pins, steel, locking	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	
Pivots, steel, for elevating arcs	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	Do.
Plates, metal, elevating	–	–	–	–	–	1	–	–	–	–	–	–	–	–	–	Do.
Punches, vent	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	
Rings, copper, vent-piece	–	–	–	1	1	1	1	1	1	1	1	1	1	–	–	Some 40-prs. of 32 cwt. have no room for an indicator ring.
Rings, indicator	1	1	1	1	1	–	–	–	–	–	–	–	–	–	–	
Rings, tappet	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	
Saddles, metal	1	1	†1	–	–	–	–	–	–	–	–	–	–	–	–	
Scales wood, side	1	–	–	1	–	1	–	–	–	–	–	–	–	–	1	
Screws, breech	1	1	1	‡1	‡1	1	1	1	1	1	1	1	1	–	–	
Screws, copper, set, right-hand	–	–	–	–	–	1	1	1	1	1	1	1	1	1	–	
Screws, copper, set, left-hand	–	–	–	–	–	1	1	1	1	1	1	1	1	1	–	
Screws, fixing, cover, vent	–	–	–	–	–	–	–	–	–	–	–	–	–	7	5	
Screws, fixing, crutch	–	–	–	2	–	2	–	2	–	2	–	2	–	–	–	The A pattern gun of 72 cwt. has 4 fixing screws.
Screws, fixing, metal saddle	6	6	6	–	–	–	–	–	–	–	–	–	–	–	–	
Screws, fixing, plate, elevating	–	–	–	–	–	4	–	–	–	–	–	–	–	–	–	See pins, pivot, elevating.
Screws, preserving, crutch*	–	–	–	–	2	–	2	–	2	–	2	–	2	–	–	
Screws, preserving, pin, friction tube*	–	1	1	–	–	–	–	–	–	–	–	–	–	–	–	
Screws, preserving, guide-plate*	–	1	–	–	1	–	–	–	1	–	1	–	1	–	–	
Sights, centre, fore	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	
Sights, centre, hind	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	
Sights, instructional, wood	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	
Sights, tangent	2	2	-2	2	2	2	2	-2	-2	2	2	2	2	2	2	-Gun-metal.
Sights, trunnion	-2	-2	2	-2	-2	-2	-2	2	2	2	2	2	2	-2	-2	-Drop.
Sockets, metal, hind centre sight	–	–	–	–	–	–	–	–	–	–	–	–	–	1	–	
Sockets, metal, tangent sight	2	2	-2	–	–	–	–	–	–	–	–	–	–	2	2	-With two set screws.
Stops, for stopper, breech	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	Issued in certain proportions as required.
Stoppers, steel, breech	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	
Straight-edges, for testing breech-screws and vent-pieces, &c.*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Vent-pieces	1	1	1	1	1	1	1	1	1	1	1	1	1	–	–	
Wedges, with moveable handles	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1	
Wires, priming	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	

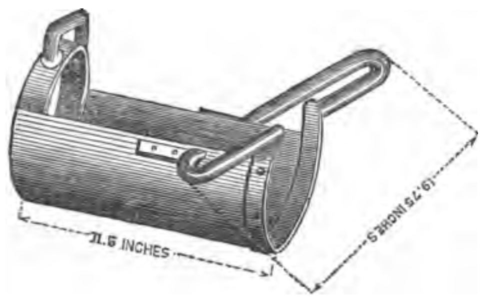
* Universal patterns.
† Different patterns for A and B guns.
‡ The breech-screws for the 40-pr. of 35-cwt. and 40-pr. of 32 cwt. have threads of different pitch and therefore are not interchangeable.

NOTE.—All the above are interchangeable with guns of the same nature, excepting † ‡.

Remarks on the Miscellaneous Stores for B.L. Guns.

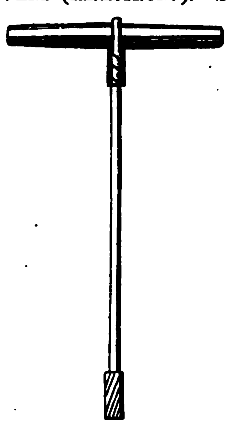
(See R.G.F. Table, page 92.)

Bearers, Shot.



These shot bearers are of iron, with three handles covered with leather, and are so made that the projectile cannot be dropped from them. They are known as "Alderson's pattern." Two are issued for each 7″ gun.* § 919.

Bits, Vent (Armstrong). Scale ¼.



The Armstrong vent-bit is of steel, with a cross-handle of wood (similar in shape to a gimlet). It is used to clear the channel of vent-pieces, should the copper bush become burred, and there is but one pattern for all natures. One to four 7″ or 40-pr. guns. For field service 1 per division. § 842.

Bits, Vent (Sea Service).

This is identical with the land service pattern. See Irons, priming.

Bushes.

Bushes, breech, iron, thick.—Two inches long, half-inch thick, and is screwed into the breech end of the A tube of 7″ guns. § 399.

Bushes, breech, iron, thin.—Three inches long, quarter-inch thick, and is screwed into the thick bush. *Spare,* 1 per gun. § 467.

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* The proportion of stores is taken from "Royal Warrant and Regulations for the "equipment of Her Majesty's Army (1870) elsewhere than India."

The bushes for these guns (7-inch) were originally of copper two inches long and half-inch thick, but this metal being found too soft for the heavy charge, the thick iron bush was substituted. This bush not having sufficient length of thread, was liable to shift, hence the introduction of the thin bush. Guns so altered are marked on the right trunnion D.B., *i.e.*, double bushed; and those made since 1st April 1862 use the thin bush only, and also D.B. guns when requiring re-bushing.
See also § 661. See pages 61–183.

§§ 526, 530. See also § 1145. *Bushes, breech, copper.*—Screwed into the breech end of the A tubes of 40-pr. breech-screw guns and under, and projects ·03 inch so as to enable it to be refaced. *Spare,** 2 per gun. (See pages 61–183.)

NOTE.—Wedge guns requiring re-bushing or re-venting must be sent to the Royal Gun Factories for repair.

§ 1232. *Bushes, copper, vent-piece.*—A set comprises two pieces. See page 63. *Spare,** 1 to two 7″ guns; 1 to two 40-pr. for Garrison Service, and 1 for each gun for Field Service.

Clamps, Moveable, for Tangent Sights.

§§ 1144, 1357. The moveable clamps are of gun-metal. See pages 69–72.

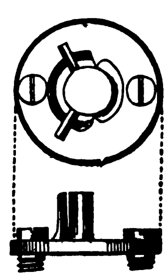
Collars, Leather, for Breech-Screws.

§ 845. This collar fits on the breech-screw of 12-pr. guns, in rear of the breech. When the vent slot was widened for a thicker vent-piece some of the threads of breech-screw were exposed, and this collar protects that part. It can be pared as the copper is faced away.

Covers, Metal, for Vents.

§ 997-1182. These covers are attached to the upper part of the breech and form part of the locking arrangement of the wedge guns. *See* page 67.

CRUTCHES, IRON. Scale ½.



§§ 27, 688. The vent-pieces of 40-prs. and smaller natures for sea service are fitted with a crutch, attached round the mouth of the vent channel by two screws. A slot is cut in the horizontal part of the crutch, through which the friction bar of the quill tube passes, thus the head of the tube is supported, and the liability to its being broken off prevented when pulling the lanyard.

With guns used for field marine purposes the crutch has two slots so as to enable them to be fired from the left side when on land.

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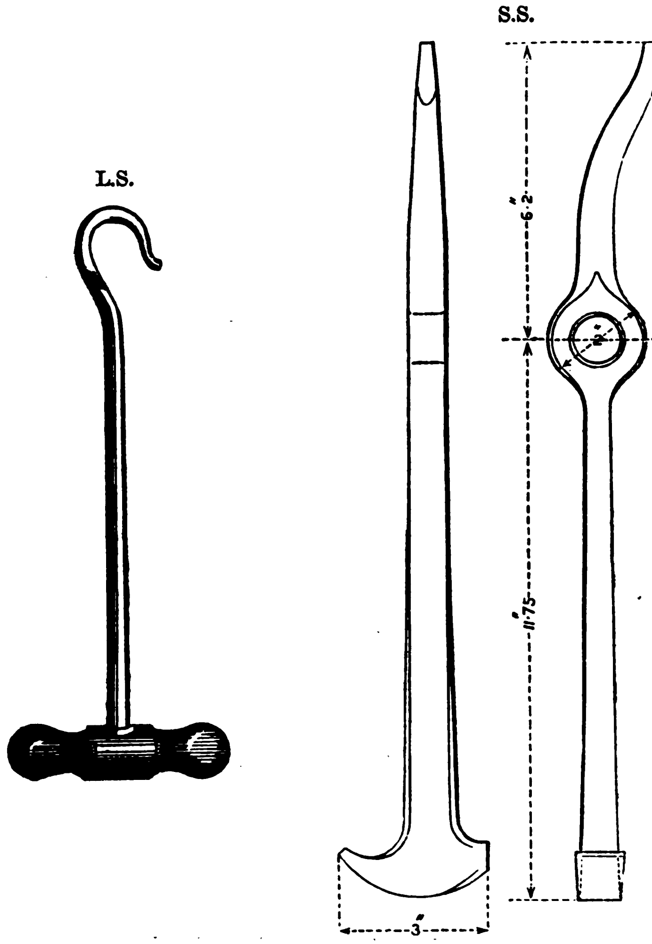
* These copper articles should be carried in some place where they would not be liable to be injured, or put out of shape.

The above vent-pieces not having sufficient space on the top for the insertion of a friction tube pin necessitates the use of the crutch.

EXTRACTORS, TIN-CUP.



The tin-cup extractor for *L.S.* is an iron hook with a wooden cross-handle. One to each gun. § 738.

For *S.S.* it is an iron lever with a barbed hook at one end to extract the tin cups, whilst at the other end it has a curved-shape hammer, used as a "lever lifting joint." § 1259.

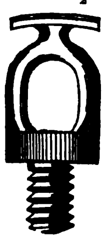
The above are only used with 7" guns. The store of L.S. extractors having been exhausted the S.S. pattern is issued in its place. Order dated 27/6/72.

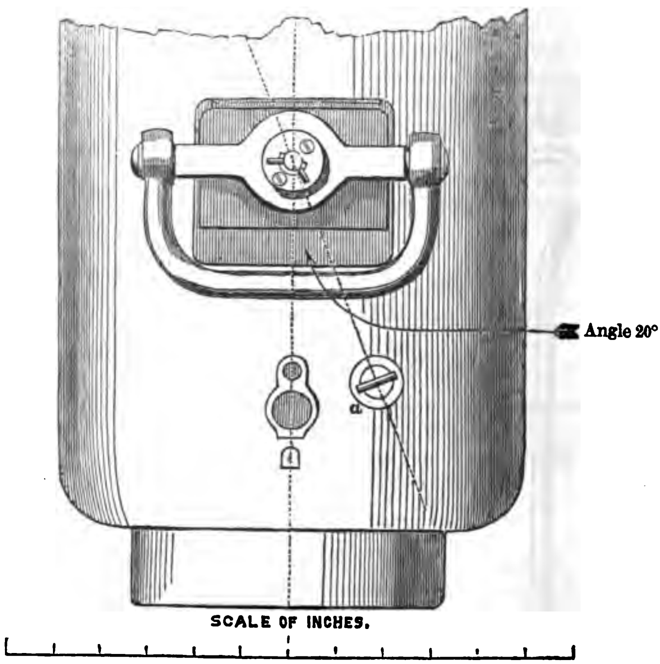
Eyes, Elevating (with Bolt, Washer, and Keep-pin).

The elevating eyes are of iron, and are screwed underneath the breech of L.S. field guns only. The 20-pr., 12-pr., and 9-pr. are double-headed, but the 6-pr. is solid-headed; the heads of the elevating screws will therefore respectively be single-headed and double-headed. §§ 178, 690, 717, 718, 998. See also § 102.

GUIDE-PLATES.

Scale ½.





a Guide-plate.

§§ 476, 688. Guide-plates are of steel, and one is screwed in at the right rear of the vent slot to guide the lanyard—which passes through it—direct on the quill friction tube. It has a cross-head on the top, to which a loop on the lanyard can be attached when the gun is loaded, and so prevent the gun being fired accidentally. The navy alone use it, as they fire their guns from the rear immediately the object is in line, and this guide-plate enables the gunner to have a steady and direct pull on the lanyard while looking over the sights.

Implements, Facing.

§§ 515, 516, 574, 575, 745, 1073. *For detail of facing implements* see *Table annexed.* 7″ one per district, one in reserve; 40-prs. one per battery, one in reserve; other guns one per battery.

Detailed List of Facing Implements for Rifled B.L. (Breech-Screw) Guns.

6-prs.

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	L	1
Blocks, breech bush copper, finish boring	K	1
Blocks, breech bush copper, screwing in	H	1
Blocks, breech bush copper, upsetting	I	1
Blocks, vent-piece ring, angle facing	N	1
Guard, wood, for vent-piece	Q	1
Guides, in breech-screw	D	2
Guides, in powder chamber	E	1
Guides, wood (block upsetting), two parts	O	1
Key, for fixing knives	F	1
Knives, breech bush copper, cutting out	G	1
Knives, breech bush copper, facing	M & M1	2
Knives, breech bush copper, rough boring	J	1
Lever	B	1
Punch, for pin in spindle	R	1
Spanner, for stop washers	P	1
Spindle	A	1
Washers, stop	C	2

12 & 9-prs.

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	I	1
Blocks, breech bush copper, finish boring, 3·125 diameter	F1	1
Blocks, breech bush copper, finish boring, 3·2 diameter	F2	1
Blocks, breech bush copper, screwing in	D	1
Blocks, breech bush copper, upsetting	C	1
Blocks, vent-piece ring, angle facing	J	1
Guard, wood, for vent-piece	S	1
Guides, in breech-screw	M	2
Guides, in powder chamber, 3·125 diameter	N1	1
Guides, in powder chamber, 3·2 diameter	N2	1
Guides, wood (block upsetting), two parts	R	1
Key, for fixing knives	O	1
Knives, breech bush copper, cutting out	K	1
Knives, breech bush copper, facing	G & G1	2
Knives, breech bush copper, rough boring	E	1
Lever	B	1
Punch, for pin in spindle	P	1
Spanner, for stop washers	Q	1
Spindle	A	1
Washers, stop	L	2

20-prs.

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	K	1
Blocks, breech bush copper, finish boring, 3·875 diameter	I1	1
Blocks, breech bush copper, finish boring, 3·94 diameter	I2	1
Blocks, breech bush copper, screwing in	G	1
Blocks, breech bush copper, upsetting	M	1
Blocks, vent-piece ring, angle facing	L	1
Guard, wood, for vent-piece	P	1
Guides, in breech-screw	C	2
Guides, in powder chamber, 3·875 diameter	D1	1
Guides, in powder chamber, 3·94 diameter	D2	1
Guides, wood (block upsetting), two parts	Q	1
Knives, breech bush copper, cutting out	F	1
Knives, breech bush copper, facing	J & J1	2
Knives, breech bush copper, rough boring	H	1
Key, for fixing knives	N	1
Lever	B	1
Punch, for pin in spindle	R	1
Spanner, for stop washers	O	1
Spindle	A	1
Washers, stop	E	2

40-prs. (*See* Note.)

In a box, with hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush copper, angle facing	G	1
Blocks, breech bush copper, cutting out	D	1
Blocks, breech bush copper, finish boring, 4·91 diameter	F1	1
Blocks, breech bush copper, finish boring, 4·96 diameter	F2	1
Blocks, breech bush copper, screwing in	E	1
Blocks, breech bush copper, upsetting	M	1
Blocks, vent-piece ring, angle facing	H	1
Collar, for feed motion	B	1
Guides, in breech-screw	A1	1
	A2	1*
Guides, expanding, in powder chamber	C	1*
Guides, wood (block upsetting), two parts	N	1
Handle to hold blocks in vent chamber	P	1
Lever	J	1
Punch, for knives in blocks	K	1
Punch, for pin in spindle	L	1
Spanner, for stop washers	R	1*
Spindle	I	1
Washers, feed	O	1*
Washers, stop	Q	1*

7-inch.

In a box, with tray, hinges and hasps, and padlock with two keys.

	Letter.	No. of each.
Blocks, breech bush iron, cutting out, boring, facing, tapering, and angle facing.	G	1
Blocks, breech bush iron, screwing in, and rough boring.	F1	1
Blocks, vent-piece, angle facing	K	1
Guard, wood, for vent-piece	O	1
Guides, in breech-screw	C	2
Guides, expanding in powder chamber	D	1
Handle to hold blocks in vent chamber	P	1
Knives, cutting out, breech bush, thick iron	E2	2
Knives, cutting out, breech bush, thin iron	E1	2
Lever	B	1
Punch, for pin in spindle	N	1
Spanner, for stop washers	M	1
Spindle	A	1
Washers, stop	J	2

Note.—This set of 40-pr. Facing Implements is the new pattern; the old pattern, which is not to be considered obsolete, consists of the same articles, with the omission of those marked *, and the insertion instead of the "Guide expanding," Guides in powder chamber { 4·91 diameter — C 1 — 1. / 4·96 diameter — C 2 — 1. } See "Changes in Patterns," § 1073, No. 5.

Instruments taking Impressions of Bores of Guns.

§ 1312. See also § 1625. For taking impressions of bores of guns there are two sets of instruments. The small set (No. 2) is used for guns up to 20-pr.; the other (No. 1), from 40-pr. upwards, both M.L. and B.L. A set consists of a semi-cylindrical iron frame, about 2 feet long, connected with an iron tube in such a manner that by screwing up a rod which passes through the tube the frame can be worked up or down.

Upon this frame a gun-metal or iron plate, corresponding to each calibre of gun is screwed, and when an impression is required gutta percha is spread on the plate, and by means of the rod is pressed against the defective part.

Plates are not required for the 6-pr. or 40-pr. guns, as the frames answer the purpose.

Instruments, Sighting, Set.

§§ 1061, 1096. For sighting instruments *see* page 74. Special issue only. *See* Ordnance Select Committee Proceedings, 1867.

*Irons, Priming.**

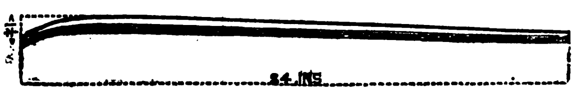
§ 1212. The pricker only is issued for L.S. guns (64-pr. wedge).

It is issued to prick the cartridge, and is 12 inches in length. One for each gun.

Levers.

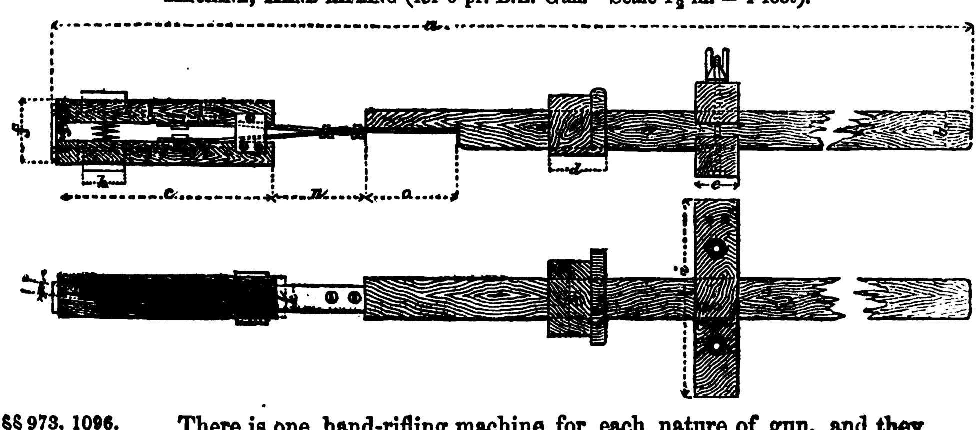
Levers, breech-screw.—*See* page 65.

Lever, Iron, for releasing Vent-piece. Scale 1 in. = 1 foot.



§ 769. See also § 1484. *Lever, iron, releasing vent-piece.*—Is an iron crowbar about 2 feet 10 inches long, for prizing out the vent-pieces of 7-inch guns when they jam. One per gun.

Machine, Hand-rifling (for 6-pr. B.L. Gun. Scale 1½ in. = 1 foot).



§§ 973, 1096. There is one hand-rifling machine for each nature of gun, and they are nearly all alike in pattern. They are for the purpose of filing

* By clause 196, Army Circular 1/11/71, the "Bit" and "Drift" formerly issued for Land Service are made obsolete.

down any metal that may be turned up in the bore by the premature bursting of a shell, or other cause. The machine consists of—

- 1 Bar, working, (*b*) with cross-handle. (The 12-pr., 9-pr., and 6-pr. have no cross-handles.)
- 1 block, guide (*d*).
- 2 cutters, file (*h*).
- 1 distance piece, in halves, with bolts and nuts (*e*).
- 1 head, filing, with springs (*c*).
- 2 screws, fixing.

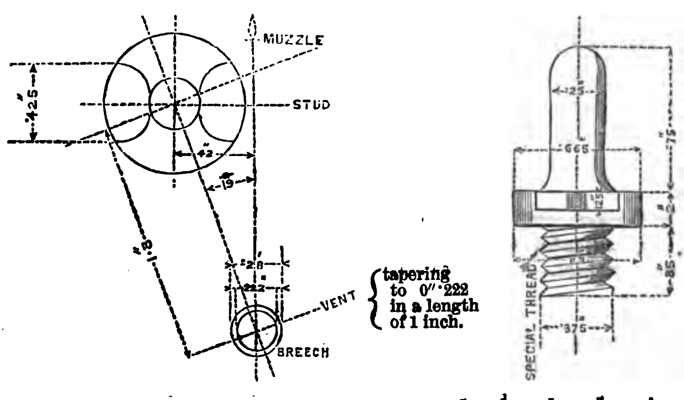
The filing head is of hornbeam wood, and is grooved like the barrel of the gun. The head is expanded by means of long springs, in the 7″ and 64-pr. there are two, in the other natures one, and small files can be fitted on either side of the head which are kept up to their work in the bore by a spiral spring fixed beneath them.* One file is for the grooves and the other for the lands, and they are shaped accordingly; only one file at a time can be used. When required to be used the file for the lands or grooves (according to circumstances) is fixed and worked backwards and forwards until the bore is smooth. The guide block, which is placed in the muzzle, keeps the bar in the centre, and the distance piece is clamped on the bar at the ascertained distance of the flaw, &c. from the muzzle, thereby ensuring the action of the file on the proper place. One per siege train of each nature, 7″ 64-pr. and 40-pr.

Patch, Metal, Elevating.

These patches are made of gun-metal, and screw into the elevating eye holes of 12-pr., 9-pr., and 6-pr. guns when fitted for sea service. The 9-pr. patch has a steel screw. §§ 717, 718. See also § 102.

Pins.

Pin, Friction Tube.



Pins, friction Tube, are of wrought-iron, case hardened, and are inserted 1″·3 to the left front of the vent channel of 7″ vent-pieces, and 40-pr. wedge guns for sea service only. Two holes are drilled close to each other, in case a pin should be broken, and the broken part remaining unable to be extracted, the spare hole can be used. The loop of the quill friction tube fits over the pin, and the mouth of the vent being rimed out to a depth of 1 inch, giving the tube a little play, ensures the pull of the lanyard acting upon the loop of the tube. The pin is now 1 inch long to prevent a liability of the loop slipping off. See *crutches, iron.* §§ 1141, 1184, 1210. § 1410. See also §§ 1148, 1861.

Pins, keep, lever.—See page 65. *Spare,* one per 7″ and 40-pr.; two for other guns.

Pins, steel, locking.—See page 67, wedge guns. *Spare,* one per gun. § 997.

* The 7″ and 64-pr. have no spiral spring, the double spring being sufficient for the purpose.

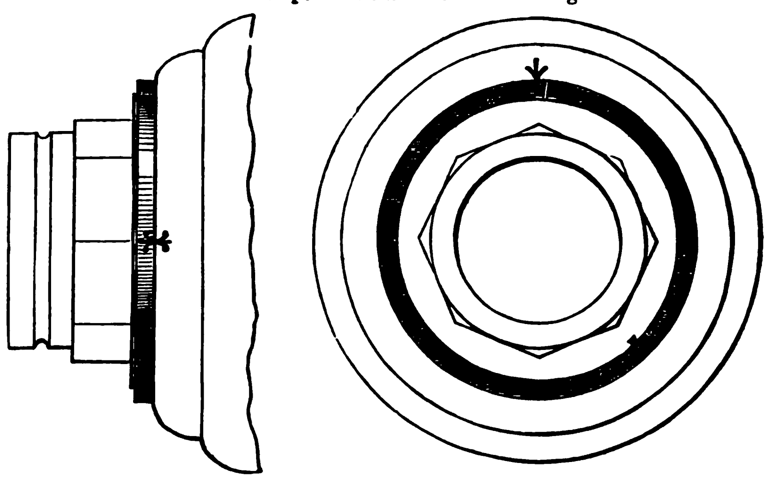
Punches, Vent.

§ 1533. Vent punches are of steel, similar in shape to the drifts, but with a round top, and are intended to be *hammered* should the vent be stopped up with anything that cannot be removed by the bit or drift. One per 64-pr. and 40-pr. wedge guns.

Rings.

§§ 472, 526, *Rings, copper, vent-piece.*—Have a half dovetail on the inner side,
530. See also which prevents the passage of the powder gas down between it and the
§ 528. iron of the vent-piece. It projects from the face of the vent-piece when new ″·05, so that it can be re-faced from time to time, as it is found to wear. Small channels are cut on the inside of the ring to allow the confined air to escape when placing it on the vent-piece. *See* page 63. *Spare,* two per field gun; they should be carried in some place where they are not liable to be injured or put out of shape.

Rings, Indicator (for 7″ B.L. Gun).
The shaded portions show the indicator ring.



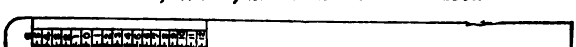
Top view, tappet removed. Rear view, tappet removed.

§§ 790, 1033. *Rings, indicator.*—*See* page 66.
Rings, tappet.—*See* page 65.

Saddles, Metal.

These metal saddles form the vent rest for the 7-inch guns, and are attached to the gun in rear of the vent slot by means of screws. The saddle for the 72 cwt. gun A is about 2¼ inches shorter than that for the B gun (the breech of the latter being longer than the former), and is fixed with four screws. All the other saddles have six screws. The saddles for the 82 cwt. gun are stouter made than those of the 72 cwt., and the position of the holes for fixing them is slightly different.

Scale, Wood, Side. Scale 1″ = 1 foot.



§ 1204. The wood side scale is used by the navy for broadside guns independently of all other sights, when the object to be hit is obscured by smoke, &c., thereby rendering the other sights useless. It must be used in connexion with the ship's pendulum, which shows the heel of the vessel, and the number of degrees of elevation or depression to be added or deducted from the required range, *i.e.*, if firing from the windward

side, and the pendulum showed 3° of heeling over, ***deduct*** 3° from the correct elevation for the range of the object aimed at to allow for the inclination of the ship's deck. If firing from a leeside the course to be pursued is *vice versâ*.

These side scales are adjusted to the rear chock of the carriage with the zero notch coinciding with a point on the vertical line intersected by the horizontal line cut on the right side of the breech, the gun being horizontal. They are graduated to give 6° depression and 12° elevation, the radius being the distance from the centre of the trunnion to the point of intersection on the side of the breech.

Screws.

Screws, breech.—See page 64. *Spare,* 7″ and 40-pr., one to 10 guns; over 10 two. §935, 901–906, 1034, 829.

Screws, copper, set, right-hand and left-hand.—Are used for the purpose of clamping the tangent sight, and pass through bosses in the tangent sight ring. These set-screws for the 20-pr., downwards, are attached to the guns by a small chain. *Spare,* one of each to six 64-pr. guns. *See* page. 72.

Screws, fixing, cover, vent.—Wrought-iron, and fasten the vent cover (in connexion with the locking arrangement of wedge guns) to the gun.—See page 67. § 997–1182. § 688.

Screws, fixing, crutch.—Wrought-iron, and attach the crutch to the top of the vent-piece.

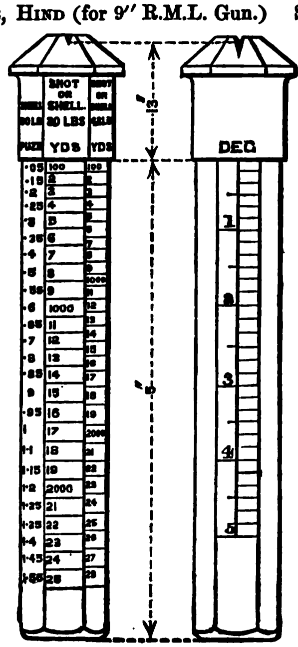
Screws, fixing, metal saddle.—Wrought-iron, and attach saddle to 7″ guns. *Spare* one per gun. § 485.

Screws, preserving. — Wrought-iron. Occupy the holes for the crutch, friction tube pin and guide-plate, when the gun is used for land service, *and mounted.* When dismounted, those in the gun are removed and the holes filled with grease, to prevent the screw heads from being broken off. § 30.

Sights.

Sight, centre, fore.—Is similar to the drop trunnion sight, and placed midway between the trunnions on the top part of the gun. § 997.

SIGHT, CENTRE, HIND (for 9″ R.M.L. Gun.) Scale, half size.



§§ 297, 1476. *Sight, centre, hind.*—A gun-metal hexagonal tubular bar (graduated to 5°) situated in rear of the vent cover, and let into a gun-metal socket in the breach of the gun at an angle of 2° 16′. It has no deflection scale.

These sights can be used for the purpose of laying at short ranges, and the 64-pr. is the only B.L. gun that uses them.

§ 1480. *Sight, instructional, wood.*—Hexagonal in shape, and an enlarged model of the tangent sight. Rectangular are also issued on demand.

§§ 1143, 1476. § 872. *Sight, tangent.*—See page 69. *Spare* one to six (or under) 7″, 64-pr. and 40-pr.

§ 872. *Sight, trunnion.*—See page 73. *Spare.*—See tangent sight. For *siege* service one to three 7″, and one to six 64-pr., 40-pr., and under.

Sockets, Metal.

§ 1481. These gun metal sockets are for the hind centre sight and tangent sight.—See p. 72. *Spare* one to six, 7″ guns of 72 cwt., with set screws.

Stops for Stopper, Breech.

§§ 997–1182. *Stops for breech stoppers,* see page 66, wedge guns.

Stoppers, Steel, Breech.

§§ 997–1182. *For breech stoppers,* see page 67, wedge guns. *Spare* one to five 64-prs. over 5—2. For siege service one to six 64-prs. and under.

Straight Edges for testing Breech-screws, &c.

§ 1016. The straight edges are of steel, 18″ × $1\frac{1}{2}$″ × $\frac{2}{10}$″. See page 183.

Vent-pieces.

§ 1185. *For vent-pieces,* see page 62. For field batteries, two vent-pieces per gun are issued; one is carried in the gun, one at the side of the trail, and two in addition per battery. Garrison and siege batteries have three per gun.

Wedges with Moveable Handles.

§§ 997–1182. *For wedges,* see page 67, wedge guns.

Wires, priming.

§ 1212. *Priming wire* is the naval designation for the land service "pricker."

CHAPTER VII.

MANUFACTURE OF HEAVY RIFLED M.L. GUNS AND THEIR FITTINGS.

Difference between the original and present construction.—*Details of Manufacture of a 7-inch Gun, Mark III.*—A-Tube of Steel.—Toughened in Oil.—Water test.—B-Tube.—Breech coil or jacket formed of (1) Triple coil; (2) Trunnion-ring; (3) Double coil.—Building up the Gun.—Processes before Proof.—Cascable.—Gas Escape.—Engraving.—Finish Boring.—Broaching.—Lapping.—Rifling.—Temporary Venting.—Manufacture of Guns above 7-inch calibre.—8-*inch, Mark III.*—9-*inch, Mark IV.*—10-*inch, Mark II., and higher natures.*—*Examination and Proof.*—Processes after Proof.—Lapping.—Obtaining preponderance and weight.—Lining and Sighting.—*Sights.*—*Venting and Position of Vent.*—Marking.—Adjusting the fittings.—Final inspection and Painting.

Difference between the "original" and present construction.

Until April 1867 all our rifled M.L. guns were built up like the B.L. guns—of wrought-iron coils shrunk together successively on Sir William Armstrong's original plan. The plan proposed by Mr. R. S. Fraser, of the Royal Gun Factories, was then adopted; but some guns in former estimates being still in arrear, manufacture on the original construction did not cease altogether until March 1868.

Mr. Fraser's plan is, as stated in a previous chapter,* an important modification of the original method, from which it differs principally in building up a gun of a few long double or triple coils instead of several short single ones and a forged breech-piece.

For example, in addition to the steel barrel and cascable, a "Fraser" 7-inch gun has only two separate parts, viz., the breech coil and *B* tube (or as they are sometimes familiarly called, the "jacket and trousers"), whereas the 7-inch gun of original construction has a forged breech-piece, a *B* tube, a trunnion-ring, and six coils—nine distinct parts—which are shrunk on separately (see Mark I., Plate III.).

The formation of a double or triple coil is a simple forge operation, but great expense is saved by its means, as there is much less surface to be bored and turned, for, each coil having to be made as smooth as glass and at the same time true to gauge (to a thousandth of an inch), it follows that it must be cheaper to have a few thick ones in lieu of many thin ones. For the same reason there is also less waste of material; for although the turnings are afterwards worked up into bars, iron in its scrap state is only worth one-third of its forged value.

Moreover, time and labour are also saved in having fewer pieces to move from workshop to workshop; for instance, in the case of a gun of original construction, when a coil was shrunk on, the mass had to be moved from the shrinking pit to the turning lathe, and turned down for the next coil, and so on, coil by coil, until the gun was built up; but in the new construction only two or three separate shrinkings are required, and it is computed that where fifty tons were moved in the former case, only seven are moved in the latter.

* See Chapter I., page 17.

From these circumstances, combined with the employment of cheaper iron, a Fraser gun can be made at two-thirds of the cost of a gun of the same nature as originally manufactured, while the experiments which were carried out previous to the introduction of this construction* clearly proved that guns of this pattern are at least quite as trustworthy and serviceable as those of the original pattern.

Up to 1869 Fraser guns were made on the same type as the 7-inch gun, Mark III., about to be described, which construction is still retained for 7-inch and 8-inch guns. Since that date, however, 9-inch and heavier guns have been made with the wrought-iron over the breech in two layers of coils. The "Mark"† of each calibre of gun approved for future manufacture is as follows, viz.:—For 7-inch and 8-inch guns, Mark III.; for 9-inch guns, Mark V.; for 10-inch, 11-inch, and 12-inch, 25 ton guns, Mark II.; and for 12-inch, 35 ton guns, Mark I. (see Plates of guns).

The following is a short account of the manufacture of the latest patterns, the 7-inch gun being taken as the type. (See page 105.)

Details of the Manufacture of a 7-inch Gun, 7 tons, Mark III.‡

The gun consists of:—

An inner barrel or tube of steel (*A* tube).
A *B* tube.
A breech coil.
A cascable.

A tube. The steel for the tube is received from the contractors in the form of a solid ingot, which is rough turned, care having been taken to fix it truly central in the lathe by means of a chuck at the muzzle and the centre at the breech. In this operation a lip or collar is formed at the muzzle to facilitate the lifting of the tube in and out of the furnace and oil bath; the slice for testing is also cut off the breech end during the rough turning. The tube remains in this state until the slice has passed through the required tests.§

Rough boring and turning. The block is next bored roughly from the solid, $6\frac{1}{4}$ inches of diameter being taken out by one cut in segmental chips $\frac{1}{8}$th of an inch thick. The boring head is the ordinary shaped "half-round bit" with one pointed cutter set angularly, and three steel burnishers. The average time for this rough boring is 56 hours. After this, the conical chamber (which is in all Fraser guns) is roughly formed by means of a cylindro-conoidal head with one long cutter and six steel burnishers, two on the taper part and four on the cylindrical. Average time 12 hours. Rough and fine boring, forming the chamber, and broaching, are all effected in the same horizontal machine, the difference being in the shape of the boring head and cutters.

Toughening in oil. The tube thus formed is now ready for toughening in oil. This consists in heating the roughly bored tube (from 4 to 5 hours) to the approved temperature in a vertical furnace, and then plunging it bodily into an adjacent bath of rape oil, in which it is allowed to cool and soak till next day, generally 12 hours or more.

"The tube is lifted by a powerful crane, and placed in a perpendicular position in an upright furnace; an iron coil, about 6 inches in depth and about 1 inch longer in diameter than the diameter of the block of

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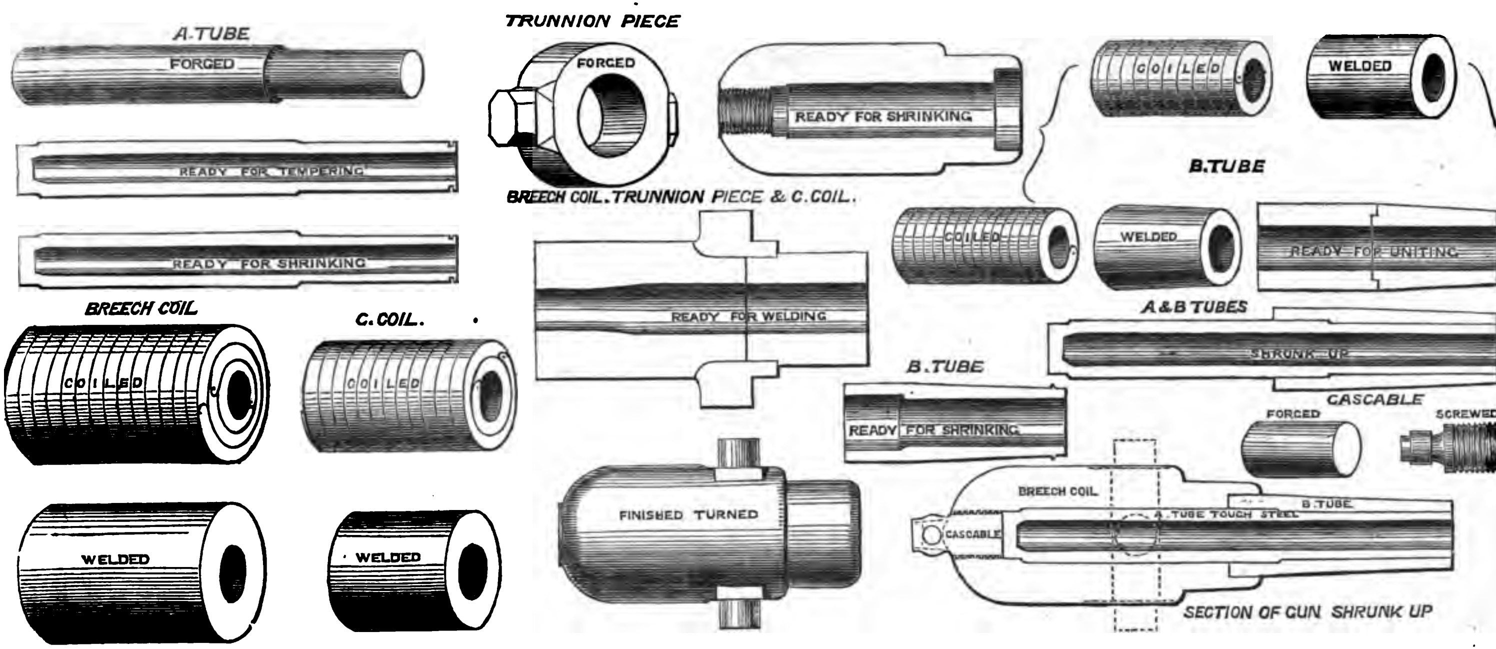
* See Chapter I., page 18.
† In November 1867 the word "Mark" was substituted for "Pattern." *See* § 1545.
‡ 7-inch guns, $6\frac{1}{2}$ tons, Mark III., are identical in manufacture, except as to length.
§ See Chapter IV., page 44.

Diagram illustrating various Stages of Manufacture of a 7-in., 8-in., or 9-in. R.M.L. Gun (**Mark III.**)



Note.—7-inch, Mark III., are not turned down at the muzzle end of the A tube, which is of an equal thickness throughout.

steel, is placed upon the fire bars at the bottom of the furnace for the block of steel to rest upon; beneath this iron coil is placed a piece of plate iron, to prevent the cold air as it passes through the bars coming in contact with the extreme end of the block of steel, and in order to obtain an uniform temperature at the extreme end of the block of steel, this iron coil is filled with wood ashes. The iron coil becomes filled with the wood ashes while heating the furnace to a red heat with refuse wood, previous to putting the steel in the furnace. After the block of steel is placed in the furnace, the bottom end of it is then surrounded with some short blocks of wood, the damper is not lifted until the extreme end has acquired a low red heat, after which the damper is lifted, and the block of steel is then entirely surrounded with longer pieces of refuse wood thrown in from the top of the furnace.

"After the steel has acquired the proper uniform temperature throughout, the travelling crane is brought over the furnace; the cover belonging to the top of the furnace is then removed, after which a pair of large iron tongs attached to the crane fasten themselves at the top end of the steel block or tube. The tongs are so constructed that the heavier the weight, the tighter they grip the steel; still it is found necessary to turn a small collar upon the end of the block to prevent the tongs slipping by the weight. After the tongs have fastened themselves upon the block of steel, it is drawn out of the furnace and sunk into a large iron tank about 20 feet deep, containing several hundred gallons of oil. The heated steel in passing into the oil will sometimes cause the surface oil to take fire, which, after the whole body of the steel is beneath the surface of the oil, is extinguished by closing the covers at the top of the tank, and spreading a piece of canvas over them. The tank has a water space around it in which a supply of cold water permeates for the purpose of keeping the oil cool. The best way to describe the tank is to state that it is an old steam boiler, sunk endways and perpendicular in the ground."*

Effects of toughening in oil.

The process of toughening has a bad effect in two ways; it not only warps the steel a little, but frequently causes the surface to crack. The barrel must therefore be slightly turned and bored to make it straight inside and outside, as well as to remove any flaws that may have been generated. This second boring (performed with a cylindrical boring head, fitted with five long edged cutters and five wood burnishers), increases the diameter to 6·6 inches. The time required for second boring—slight as is the cut—is 25 hours, the steel being much harder after toughening. By these means the cracks are generally removed, but several tubes have been rejected in consequence of flaws still appearing to penetrate to a dangerous depth, and lest there should be any not visible to the eye, the steel barrel is subjected to the following water test:—

Water test.

The tube being recessed on the face for a gutta percha ring, and inside the muzzle for a leather cup, is fitted with these washers and placed in a horizontal hydraulic press, and screwed tightly up between two cast-iron heads by means of two strong wrought-iron bars extending from head to head, and fitted with nuts at the outside, worked by a long spanner. The tube is then filled with water from the main through the hole in head and leather cup, and then the pipe of the press is fixed into the hole, and the pump is set to work by steam. The pressure on the interior is shown by two indicators, one vertical and one horizontal, so as to check one another. When $3\frac{1}{2}$ tons per square inch is thus indicated, the pressure is withdrawn, and if no flaw has been detected by the formation of moisture on the exterior, the tube is considered safe

* "The Management of Steel," by Mr. George Ede, of the Royal Gun Factories.

and sound. The barrel is left in this state until the *B* tube is ready to be shrunk over it.

The B Tube.

The *B* tube is composed of two single and slightly taper coils united together. **B Tube.**

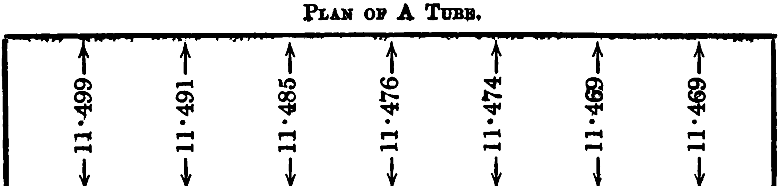
The two coils, being made and welded in the usual way, they are faced and reciprocally recessed to the depth of about one inch, and then united together endways by expanding the faucet of one coil by heat, and allowing it to shrink round the spigot of the other. This fastens the two coils sufficiently tight together to admit of the tube thus formed being placed upright in a furnace, whence, when it arrives at a white or welding heat, it is removed to a steam hammer, and receives on its end six or seven pressing blows which weld the joint completely.

The *B* tube is next rough turned, in which process a rim is formed near the muzzle for the convenience of lifting the tube in "shrinking." After this, it is rough and fine bored in the same horizontal machine.

The interior of the *B* tube having thus been brought to the degree of smoothness requisite for close contact with the steel barrel, is gauged every 12 inches down the bore. To the measurements thus obtained, the calculated amount of shrinkage (0″·003 at the muzzle, and increasing up to 0″·022 at the other end), is added; a plan is made out according to which the exterior of the *A* tube (or rather that portion of it on which the *B* tube is to go) must be turned down, in order that it shall be exactly larger than the bore of the tube by the required amount of shrinkage at the respective parts.

The plan (as illustrated by the annexed drawing), is made on a slip of paper, and together with a corresponding series of accurately measured horseshoe gauges, is furnished to the turner, who turns down the muzzle end of the *A* tube accordingly.

PLAN OF A TUBE.



The reason an *inner* tube is turned to suit an exterior one, instead of the latter being bored to suit the former is, as previously stated, that it is much easier to turn than to bore to very exact dimensions, on account of the great command which the operator has over the turning lathe, and the facility he has of testing his work by gauges, and correcting it by emery powder and oil.

The Breech Coil or Jacket.

The breech coil or jacket is composed of a triple coil, a trunnion-ring, and a double coil, made and welded together as follows:— **Breech Coil.** Triple coil.

The triple coil * is formed, as already described, by coiling three bars one over the other, and in order to weld its folds, is placed in a furnace for about seven hours, at the end of which time it is at a welding heat, whereupon it is rapidly transferred to a powerful hammer, and receives a few smart blows on its upper end, which close the folds longitudinally.

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* In diagram called "Breech Coil." Iron of large section being now (October 1872) rolled in the R.G.F., these coils are generally made double instead of triple. Greater soundness in the interior is thereby ensured, and manufacture is facilitated.

A mandril somewhat larger in diameter being then forced down, it is turned on its side, and well hammered all round to make it dense, and also to weld the three layers together. It is replaced in the furnace for about four hours, and the same process repeated at the breech end, but with a smaller mandril.

When cold, the ends are faced and the outer coil is turned down at the muzzle end to form a shoulder 10″ long for the reception of the trunnion-ring.

Double coil. *The double coil* * being welded, as above, has a shoulder formed on the lower end about 9 inches long and ¾ inch deep, so that it may enter the trunnion-ring in the after process of welding the parts of the jacket together.

Trunnion-ring. *The trunnion-ring* is made like all wrought-iron trunnion-rings, namely, of slabs of iron consecutively welded together on the flattened end of a porter bar, and gradually formed into a ring by means of, first, a small iron wedge, which is driven through the centre and punches an oval hole, and then by a series of taper mandrils increasing in size, which make the hole sufficiently large and round. The trunnion-ring has to be heated for each punching, and the occasion is used to hammer the trunnions roughly into shape, one of which is in continuation of the porter bar. Eventually the ring is cut off from the bar by means of strong blunt hatchets of steel hammered through it. The trunnion-ring is next roughly bored out.

Welded together. All three parts (triple coil, double coil, and trunnion-ring) being thus prepared, the trunnion-ring is heated to redness, lifted by a crane, and dropped on to the shoulder of the triple coil, which is placed upright on its breech end for the purpose.

While the trunnion-ring is still hot, the double coil is dropped down upon the front of the triple coil, through the upper portion of the trunnion-ring which was left projecting. The trunnion-ring thus forms a band over the joint, and in cooling contracts round the two coils, and grips them sufficiently tight to allow of the whole mass being placed bodily in a furnace, where it is raised to a welding heat in about eight hours (see diagram, page 105).

The glowing mass is then quickly placed on its breech end under the most powerful hammer in the Department. Six or seven blows on the top suffice to amalgamate the three parts together; but to make the welding more perfect on the interior, as well as to obviate any bulging inside, a cast-iron mandril somewhat larger than the bore is forced down to within 20 inches of the breech end, a series of short iron plugs being used to drive it down. The mass is then reversed, and the mandril is driven out with the same plugs, which have fallen out in the tilting over.

The breech coil thus formed is turned in a very powerful lathe; the operation takes about 50 hours.

It being impracticable to turn down the trunnion-ring in a lathe, it is slotted smooth in a self-acting vertical machine with a double motion, one of which moves the jacket round for a fresh cut at every stroke of the tool which the other works up and down accordingly.

The trunnions themselves have yet to be turned down to shape; so the jacket has to be moved for the purpose to another machine, a break lathe, in which it is made to revolve on the axis of the trunnions while the sliding cutters act on their surface.

The jacket is next rough and fine bored in a machine like that used or the *B* tube, but stronger, and the front of the double coil is recessed

* In diagram called "C" coil.

on the inside to a depth of eight inches, and broad enough to overlap the breech end of the *B* tube.

Finally, the female thread for the cascable is cut by a machine in which the jacket revolves horizontally, while the cutter is fed forward by a copying screw, one pitch for every revolution of the jacket.

Building up the Gun, or shrinking the parts together.

Shrinking the parts together.

The steel barrel and *B* tube being prepared for one another as described, are shrunk together in this manner:—The *B* tube is placed on a grating, and heated for about two hours by a wood fire, for which the tube itself forms a flue, until it is sufficiently expanded to drop easily over the muzzle end of the steel barrel, which is placed upright in a pit ready to receive it. The *B* tube is then raised, and the ashes, &c., being brushed from the interior, is dropped over the steel barrel by means of a travelling crane overhead. During the process of shrinking, a stream of cold water is poured into the steel barrel, to keep it as cool as possible, the water being supplied and withdrawn by a pipe and siphon at the muzzle. A ring of gas or a heated cylinder is placed round the muzzle or thin end of the *B* tube, to prevent its cooling prematurely, whilst a jet of cold water plays on the other end, which it is desirable should grip first; were both ends allowed to contract simultaneously, the intermediate part of the tube would be drawn out to a state of longitudinal tension, and weakened accordingly.

The *A* and *B* tubes shrunk up (see diagram, page 105), are placed in a lathe, and while one cutter fine turns the *B* tube to its proper shape and dimension, another cutter fine turns the breech end of the *A* tube according to the plan of the interior of breech coil, which has been made out on the principle already explained. The projection at the breech end is then removed and the end faced.

The shrinkage on the steel tube being 0″·01 at the extreme breech end, 0″·02 at the shoulder round the end of the bore, and gradually diminishing to 0″·017 at the point where the jacket abuts against the *B* tube, the overlapped portion of the *B* tube is given a shrinkage of 0″·023.

The half-formed gun, composed of *A* and *B* tubes shrunk up, being next placed standing on its muzzle in the shrinking pit, the jacket is heated for about 10 hours, and shrunk on in the same manner as the *B* tube; it is, however (being nearly of the same thickness throughout), allowed to cool naturally, and, to keep the interior cool, cold water has to be forced up, fountain fashion, into the bore of the gun by a jet round which the muzzle rests.

Processes after the Gun is Built up and before Proof.

Processes before Proof.

These are:—

(1.) Screwing in the cascable.
(2.) Engraving the Royal cypher.
(3.) Fine boring.
(4.) Second rough cutting of chamber.
(5.) Finished boring.
(6.) Broaching of bore, and finishing of chamber.
(7.) Lapping.
(8.) Rifling.
(9.) Temporary venting.

Forged cascable.

(1.) *The cascable* is made of the best scrap iron. It is first forged into an oblong block, then turned cylindrical, and a bevel thread cut n it. The button is turned on it, and a hole (which is afterwards

enlarged into the loop), is drilled through one end, for the purpose of screwing it into the gun. The operation of screwing in the cascable requires great care, for the front of it must bear evenly against the end of the steel barrel, and in order that this may be the case, the end of the tube is smeared with red lead and the cascable screwed in tentatively, then unscrewed again, and filed down on the prominent parts, which are indicated by the absence of the red lead. This is repeated several times, until the equal distribution of the lead on the front shows that it bears evenly against the steel barrel.

Gas escape. At this stage, one round of thread is turned off the end of the cascable, so that there may be an annular space there, which in connexion with a channel now cut along the cascable and across the thread, will form a gas escape, or tell-tale hole, in case the steel barrel should split at the end. The channel is about $\frac{3}{8}$th inch broad, and extends $\frac{1}{10}$th inch below the thread. In all guns made before the 1st September 1869, the channel comes out directly under the loop; but in guns made since that date, it will be found at the right side, where it may be more easily noticed. The channel ought to be kept clear, and should the barrel be split at the end, some gas may be seen issuing from the hole; it is therefore advisable to keep an eye on this hole, and to cease firing should it give warning.

When at length the cascable fits properly, it is screwed in, and to prevent its moving, a hole $2\frac{1}{4}$ inches long and $\frac{3}{4}$ inch in diameter is drilled and tapped through the male and female threads in a slanting direction on the left side, and a plug is screwed in.

Engraving. (2.) While the cascable is being prepared, Her Majesty's monogram is engraved in front of the vent, the outline being marked on the gun by means of a perforated brass plate, rubbed over with charcoal.

Fine and finish boring. (3.) The gun is next removed to the boring mill, where it is fine bored to 6″·9.

(4.) The chamber is next roughly bored out with the same boring head as before.

(5.) The finished boring to 6″·997 is then performed.

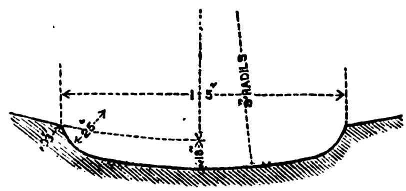
The fine boring and the finished boring are effected with the boring head used in the second rough boring, and together occupy 26 hours.

Broaching. (6.) In each boring the cutters wear a little during the operation, so that the bore becomes slightly taper towards the breech. This is of no consequence in an outer tube, as the exterior of the inner one can be turned accordingly, but the bore of the gun must be cylindrical, so broaching is employed; that is, boring the barrel by means of a cylindro-conoidal head, fitted with four long cutters at right angles to one another, and slightly tapering. The cutters are edged on the front as well as on the side, as the chamber is also finished off at this time, and for this latter purpose there is also a peculiar centre cutter for the very end of the bore.

Lapping. (7.) Still, however, the bore is not yet truly cylindrical, and lapping is resorted to, the bore being at the same time brought up to its true diameter of 7 inches. In this no cutter is used, but a wooden head, covered with lead and smeared over with emery powder and oil, is worked up and down at those portions of the bore which are indicated by the gauges as imperfect.

Rifling. (8.) The 7-inch M.L. guns are rifled with a uniform spiral, *i.e.*, with grooves having the same amount of twist at every point of the bore; and all the higher natures with a uniformly increasing spiral, *i.e.*, uniformly increasing from the breech to the muzzle. The advantage of an increasing spiral is, that the inclination of the grooves, being little or nothing at the breech, the projectile's initial motion is not checked by any resistance offered to the studs. The projectile therefore

moves quickly from its seat, and relieves the breech a good deal from the strain of the discharge.



Woolwich groove.

The groove is of the "Woolwich" shape, 1″·5 wide and 0″·18 deep, with curved edges, *i.e.* both the loading and driving edges are struck with the same radius. The bottom of the groove is eccentric to the bore, being struck with a radius of 3″. The grooves are the same width for all natures of heavy guns, but they are 0″·2 deep for the 10-inch gun and upwards; the grooves are also widened at the muzzle in these guns, in order to facilitate loading, by cutting away the loading side to a breadth of 2½″, tapering down to the ordinary width at 2″ from the muzzle. This change was introduced in October 1871. The number of grooves varies with the calibre, 7-inch guns have three, 8-inch four, 9-inch six, 10-inch seven, 11-inch, and 12-inch nine.

As a rule, about two calibres in length is left plain or unrifled for a powder chamber. The unrifled part should be as long as possible, provided that no air space is left between the smallest charge used and the base of the projectile, for the grooving tends to weaken the barrel very much and the seat of the charge should be the strongest part of the gun.

(9.) Previous to the 23rd January 1868, rifled M.L. guns were left altogether unvented until after proof, at which they were fired by means of electric wires passed in at the muzzle. Since that date, all guns are drilled and tapped before proof, and fired through a removeable steel cone vent, which is unscrewed after proof and replaced by the permanent vent; the object of this is to prevent the proper vent being strained by the large proof charge. **Venting.**

The cone of this steel vent is about ·05″ smaller than the service pattern, but after proof the cone in the gun is broached out to the proper size.

The gun is now ready for examination and proof.

8-inch Gun, Mark III.

Consists of same parts as the 7-inch, Mark III., and the processes in manufacture are identical. These guns and all higher natures (except the 13″·05) are rifled with an increasing twist.

9-inch, Marks IV. and V.*

Consists of:—

A tube.
B tube.
Coiled breech-piece.
C coil (jacket).
Cascable.

The A tube is prepared up to the point of shrinking, as already described.

The coiled breech-piece is two coils united, and being finish bored, and a thread cut in the breech end for the cascable, is shrunk on the *A* tube, after which a shoulder is formed on its muzzle end.

The B tube is manufactured like that already described, except that a recess with a hook is cut in the breech end for the purpose of joining it to the coiled breech-piece.

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* Mark V. differs from Mark IV. in preponderance only. (See page 114.)

The cascable is screwed in before the *C* coil is shrunk on in this and all guns of similar construction, the cascable thus gaining the advantage of compression due to shrinking.

The C coil is composed of a breech coil, trunnion-ring, and muzzle coil welded together, and being finish bored and turned, is shrunk on over the coiled breech-piece.

The remainder of the operations and parts are similar to those for the smaller natures.

10-inch gun, Mark II., *and higher natures of those manufactured since* 1869,

Consists of :—

A tube.
B tube.
1 *B* coil (belt).
Coiled breech-piece.
C coil (jacket).
Cascable.

The manufacture of these guns is similar to that of 9-inch, Mark V., except that there is an additional piece called the 1 *B coil,* shrunk over the steel tube between the *B* tube and coiled breech-piece. This is for convenience in manufacture, owing to the length of the gun. These guns are rifled, &c. before the jacket is shrunk on to save the labour of shifting the whole weight from one machine to another.

Examination and Proof.

Gutta percha impressions taken before proof, and bore gauged.

All guns are minutely examined before proof, and gutta percha impressions are taken of the whole length of the bore in four quarters. The bore of all guns of 9-inch calibre and upwards is also accurately gauged every three inches.

Early proof too severe.

Early rifled guns were proved with very heavy charges both of powder and shot, but it was found necessary to modify this test as it was liable permanently to injure the guns even when they did not absolutely fail. The late Ordnance Select Committee therefore, after having obtained particulars of proof of guns in nearly all the other countries in Europe,

Proof.

came to the conclusion that the proof should be based on the highest charge which the gun will fire on service,* and recommended the following proof which was approved in July 1864 and remains still in force,† viz., two rounds of 1¼ the highest service (battering) charge, and service projectiles; but, in consequence of the results obtained in recent trials with Pebble powder, experiments are being carried on to determine the future proof charge.‡

Water test.

After proof rifled M.L. guns are tested by having water force pumped into the bore, the pressure being 120 lbs. on the square inch. This test

Object.

was instituted for guns with wrought-iron barrels, having *loose* ends to ascertain that the breech was perfectly closed, for which purpose it is still used with the *converted* guns. It is also continued in guns having solid ended steel barrels, to make sure that the end has not been split at proof.

Impressions after proof compared with those taken before.

Gutta percha impressions of the bore are again taken after proof, and the bores of heavy M.L. guns are gauged. The impressions taken after proof are compared with those taken previously to ascertain that no defect of a serious character has been developed, and that slight ones have not perceptibly increased. If any should appear after proof, of which there

Further test.

is even the slightest doubt, the gun is subjected to five more rounds with service charges, and if after that the defect does not appear to have increased the gun is passed.

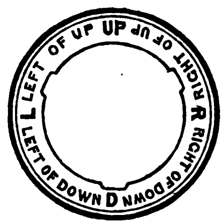
* Ordnance Select Committee Proceedings, 1864, p. 199. † §§ 934, 1186, 1233.

‡ The future proof of guns firing Pebble powder is to consist of one round with battering charge and two with proof charges, all three with service weight of shot.

The impressions of any defects of importance are cut off, the position in the gun is marked on the back, and they are registered and preserved for future reference.

Impressions of defects preserved.

Defects are noted in the following manner:—The distance is recorded in inches from the muzzle, and the position round the gun is recorded in all cases according to the diagram, looking from the muzzle, as "up," "D," "R," "L," or in intermediate positions as "R of D," "L of up," &c., &c. If a defect extends any length it is noted as in the following examples: "36″, D to L," which means a defect 36 inches from the muzzle running round the bore from "down" to "left," or "49″ to 56″ up," meaning a defect running along the top of the bore from 49 inches to 56 inches, *i.e.*, 7 inches long.



In addition to comparing the impressions, the expansion of the bore at the seat of the charge is ascertained by comparing the gaugings before and after proof. This expansion seldom exceeds a few thousandths of an inch, but it may be greater in guns having coiled barrels.

Gaugings before and after proof compared.

Processes after Proof and before Issue, common to all Heavy R. M. L. Guns.

Processes after proof.

(1.) Lapping.
(2.) Obtaining preponderance and weight.
(3.) Lining.
(4.) Sighting.
(5.) Venting.
(6.) Marking, and the "marks" denoting pattern.
(7.) Fixing on elevating plates and small fittings, sloping sides of cascable, and scoring breech.
(8.) Painting and lacquering, and final inspection.

All the above processes, except the last, are performed in the one workshop (the sighting room), and generally, but not necessarily, in the exact order given.

(1.) Every gun is *lapped* after proof, for the purpose of removing any little burs which may be thrown up on the edges of the grooves by the heavy proof rounds.

Lapping.

(2.) The meaning of the term "preponderance," as applied to modern guns, is the pressure which the breech portion of the gun, when horizontal, exerts on the elevating arrangement.

Preponderance.

To ascertain the *preponderance*, the gun is supported at the trunnions by steel bars placed beneath them, and is brought horizontal by means of long handspikes in the bore. A Kitchen's weighing machine (like that ordinarily used at railways for weighing luggage) is then placed under the breech, and a block of wood is fixed on it, touching the gun underneath midway between the elevating points. The handspikes being then removed from the bore, the pressure on the block is indicated on the arm of the machine, and is the preponderance of the gun.

In 1865 the question of preponderance in rifled M.L. guns was brought to notice with a view to dispense with it, and so enable heavy guns to be elevated or depressed more readily. Subsequently it was approved that the 8″ and 9″ guns then under manufacture should be

O.S.C. Proceedings, 1865, pp. 96, 181.

O.S.C. Proceedings, 1867, pp. 134, 221.

completed without preponderance. The preponderance of the 7-inch $6\frac{1}{2}$ tons guns was questioned in 1867. The objection to no preponderance was "that the muzzle droops while loading, and that even when the "projectile is rammed home, the gun will not follow down for elevation," but it was also stated "that the preponderance in 7-inch guns renders "depression with handspikes difficult."

§ 1461.

It was therefore approved that the preponderance of 7-inch guns of $6\frac{1}{2}$ and 7 tons, should be 3 cwt., 8-inch, 4 cwt., and 9-inch, 5 cwt. For guns above 12 tons the preponderance was not to exceed 6 cwt., nor be less that 5 cwt.

O.S.C. Proceedings, 1867, p. 221.

O.S.C. Proceedings, 1869, p. 216, § 2219.

§ 1774.

In 1869 the Admiralty requested that guns of 18 tons and upwards should have no preponderance, but as this was practically impossible, "anything under 3 cwt. was to be considered as nil." This was subsequently approved of, and on 6/12/71 it was extended to 12-ton guns.

Weight.

The actual *weight* of each gun is taken by means of a strong steelyard, to the short arm of which the gun is slung by the trunnions.

Lining and Sighting.

(3.) The object of lining is to enable the sights and elevating plates to be adjusted. The line of metal is the first line required, and is obtained as in cast-iron guns, by finding the axis of the gun and a line parallel to it along the top of the gun, but the process is much more refined and accurate. The gun is placed on a horizontal iron table, and being levelled across the trunnions and along the bore, is carefully scotched up.

Instead of using a wooden batten to find the *axis*, a centring block, capable of being pressed out so as to fit tightly in the bore, is pushed home to the breech end. From the very centre of this block, a silk thread is extended through a plate on the muzzle to an iron upright (plumbed) stand, some feet in front of the gun. The stand is then moved to the right or left until the thread grazes the centre point on the muzzle plate.

A "breech gauge," provided with a vertical slide, having been fixed horizontally on the cascable, another silk thread is stretched from the stand to the breech slide so as to pass through a point in the muzzle plate in the same vertical plane as the lower thread, and just high enough to clear the breech of the gun. This gives the position of the line of metal, which is accordingly marked for about $1\frac{1}{2}$ inch in length at the extreme end of the cylindrical part of the breech.

Vertical and horizontal lines are marked on the face of the muzzle along the slots in the plate, and short horizontal lines are marked on the right side of the muzzle, and on both sides of the breech, by means of a scribing block, the moveable arm of which is adjusted to the horizontal slot, the block resting on the table.

The horizontal and vertical axes lines are cut, as usual, on the right trunnion.

Drilling for sights.

(4.) The gun is placed under a radial drilling machine. The breech gauge and muzzle plate (the same as used for lining) are then attached, and the gun is levelled to the angle at which the tangent sights are to be inclined to the left, as the machine drills vertically. This brings the right sight higher than the left, and the right tangent sight socket nearer the vertical axis than the left. Two silk threads are stretched at one side of the gun from the breech gauge to the muzzle plate, and at the width of the socket apart. The given distance of the tangent sight socket from the line of metal being ascertained (by a gauge), the arm of the machine is brought over the spot and the hole drilled completely through the breech so as to allow of the water and turnings in the after processes to escape. The drills, &c. work between the threads which answer as a check. In subsequent borings the drills are not carried through. This operation is repeated on the other side.

The corners of the sight recesses are in future to be rounded off $\frac{1}{8}$th inch, to prevent any injury to the thin edge when moving the gun.

NATURE of TANGENT SIGHTS* and particulars of GRADUATIONS for RIFLED M.L. GUNS.

Nature of Gun.	Permanent angle of Deflection of Sights.	Length of Radius in Inches.	Graduations for Degrees.		Remarks.
			Number.	Length in Inches.	
12-inch M.L., 35 tons.					
13·05-inch M.L., 23 tons	Nil.	45	13	10·388	Side sights } No yard graduations.
		45·1	5	3·936	Centre do. } No yard graduations.
12-inch M.L., 25 tons	30′	54	12	11·478	Side.
		59·95	5	5·249	Centre.
11-inch M.L., 25 tons	2° 26′	54	12	11·478	Side.
		59·95	5	5·249	Centre.
10-inch M.L., 18 tons	1° 10′	54	12	11·478	Side.
		60	5	5·249	Centre.
9-inch M.L., 12 tons	44′	45	15	12·057	Side.
		45·1	5	3·936	Centre.
8-inch M.L., 9 tons	28′	38	15	10·05	Side.
		38·1	5	3·35	Centre.
7-inch M.L., 7 and 6½ tons	3°	38	15	10·05	Side.
		38·1	5	3·35	Centre.
80-pr. (converted) 5 tons	19′	38	15	10·05	Side.
64-pr. M.L. 64 cwts.	2° 16′	38	15	10·05	Side.
		38·1	5	3·35	Centre.
64-pr. M.L. converted 71 cwts.	2° 16′	38	15	10·05	Side.
64-pr. M.L. converted 58 cwts.	2° 16′	38·1	5	3·35	Centre.
40-pr. M.L., 35 cwt.	-	-	-	-	Experimental.
25-pr. M.L. 22 cwt.	-	-	-	-	Ditto.
16-pr. M.L., 12 cwt.	1° 50′	24	12	5·101	Side.
9-pr. M.L. Wrought-Iron 8 cwt.†	1·30	66	6	6·936	Centre
			12	14·028	
9-pr. M.L. Wrought-Iron 6 cwt.	1·30	54·6	7	6·703	Centre
9-pr. M.L. Bronze, 8 cwt.†	1·30	66	6	6·936	Centre
			12	14·028	No yard graduations.
7-pr. M.L. 150 lbs. (Steel)	3°	24·2	10	4·28	Centre
			20	8·81	Do. Wood
7-pr. M.L. 200 lbs. (Bronze)	3°	33·5	8	4·708	Centre
			17	10·241	Do. Wood

* Besides tangent sights, the Rifled M.L. guns for S.S. have wood scales used in conjunction with heel scales on the cascable, whilst 64-pr. M.L. are supplied with wood side scales (giving 12° elevation and 6° depression) similar to those for S.B. guns.

† A brass plate showing the range table is attached to left bracket of carriage.

NOTE.—The metal heads of the sights are not to be polished, as it would eventually destroy their accuracy.

The hole for the centre hind sight is drilled in the same way and at the same angle, but only of sufficient depth to admit of the sight.

For the trunnion sights the holes are drilled in a similar manner, but as they are not to be inclined at an angle the gun must be previously relevelled with the trunnions horizontal; the distance from the centre of the tangent sight holes to the centre of the trunnion sight holes is accurately measured (by a gauge) according to the radius at which the gun is to be sighted.

Fitting sockets. The bearing for the tangent sights in the metal of the gun being long and liable to rust, gun-metal sockets are fitted in by hand and afterwards fixed by side screws. There is also a gun-metal socket and clamping screw for the centre hind sight.

For the drop trunnion sights gun-metal sockets are fixed in the bottom of the hole.

Scale on cascable. The heel scale on the cascable is marked by means of a template, after which it is cut.

Sights. The sights supplied to heavy guns are similar to those already described (see page 69). They are six in number, viz., two tangent sights, two trunnion sights, and a centre-hind and centre-fore sight.

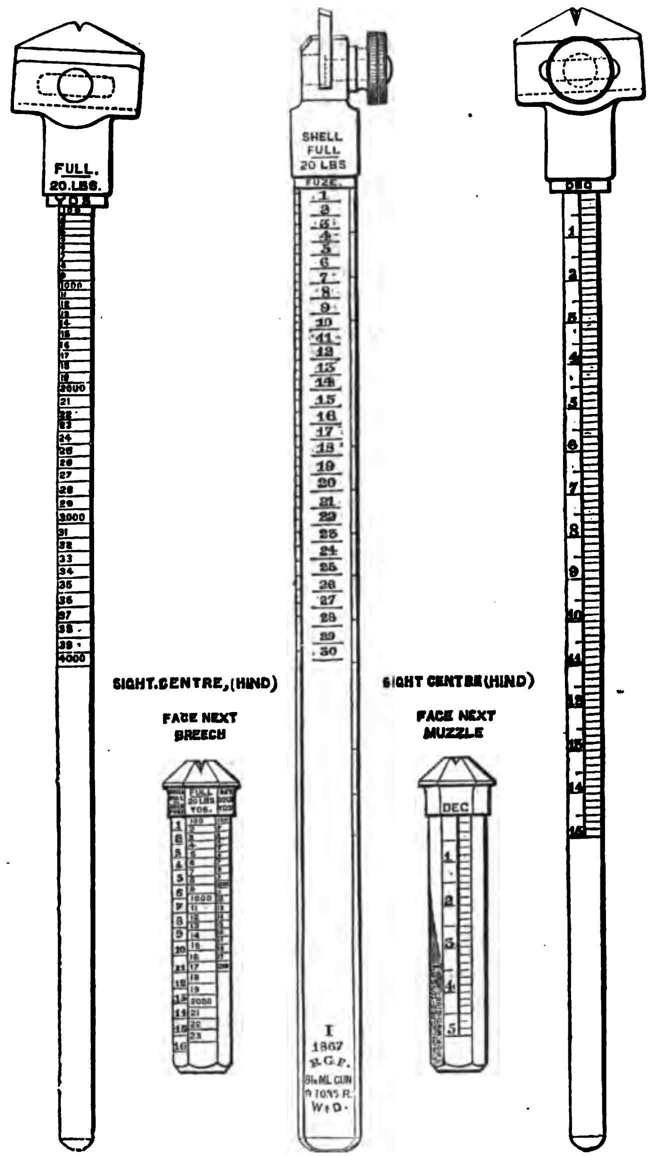
Tangent sights. The tangent sights have rectangular steel bars and gun-metal sliding leaf-heads, and are clamped with the gun-metal moveable clamp.

The nature of the gun is marked on the tangent bar, otherwise the wrong sight might be used, as the bars are all the same in section.

The graduations in use up to October 1871, previous to the introduction of Pebble powder, are shown in the woodcut on next page.

Sliding leaf Tangent Sight (8-inch R.M.L. gun). Scale ⅛.

Face next breech. Side elevation. Face next muzzle.

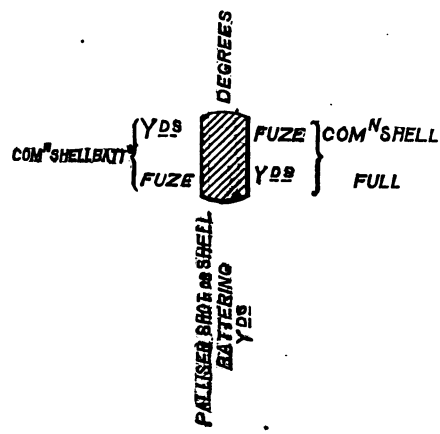


§ 2198. Regraduation was necessitated by the introduction of "pebble" powder; and advantage has been taken of this opportunity to secure, as fully as the various classes of projectiles will allow, the introduction of a uniform system of applying the information which is engraved on the sight bars.

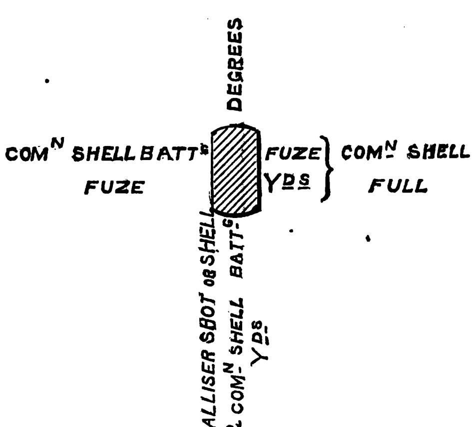
The following diagrams explain this arrangement:—

Arrangement of Graduations on Tangent Sights of M.L. Guns.

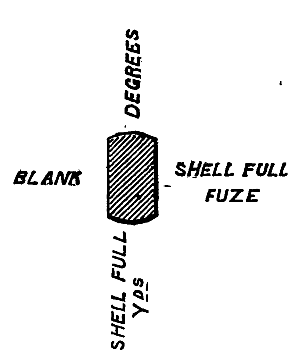
12-inch, Mark II.
10 " " II.



9-inch, Mark III.
8 " " II.
7 " " III.

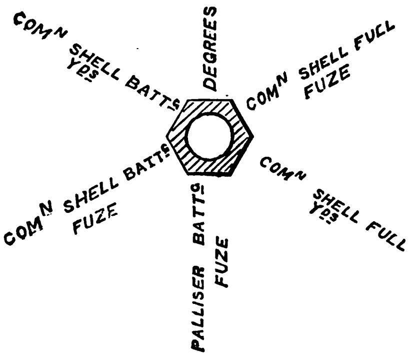


64-pr., Mark IV.

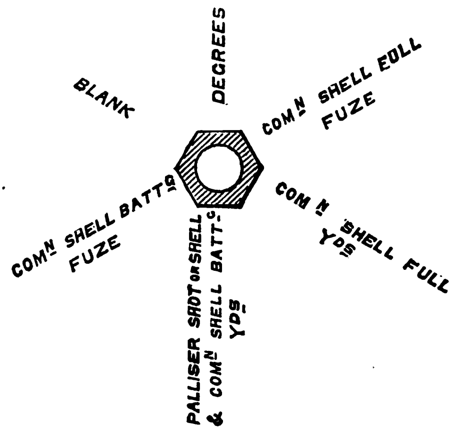


Arrangement of Graduations on Centre Hind Sights of M.L. Guns.

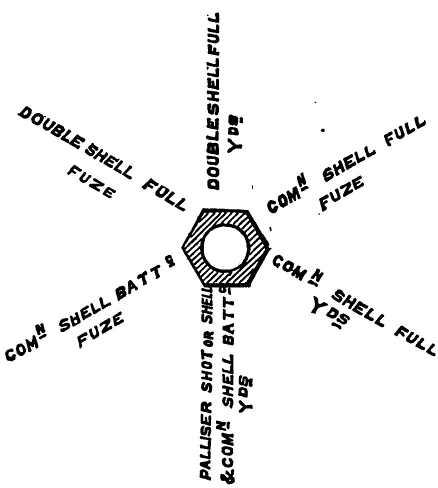
12-inch, Mark II.
10 „ „ II.



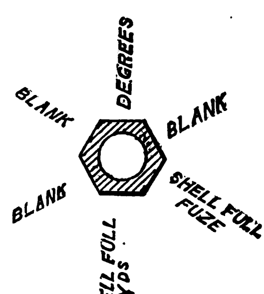
9-inch, Mark IV.
8 „ „ III.



7-inch, Mark III.



64-pr. Mark III.



The 11-inch sights are at present only graduated in degrees; they will, however, be graduated similarly to the 12-inch and 10-inch sights when the necessary data are obtained.

In connection with the preparation of these sights the following alterations have been approved, and have been embodied in the patterns.

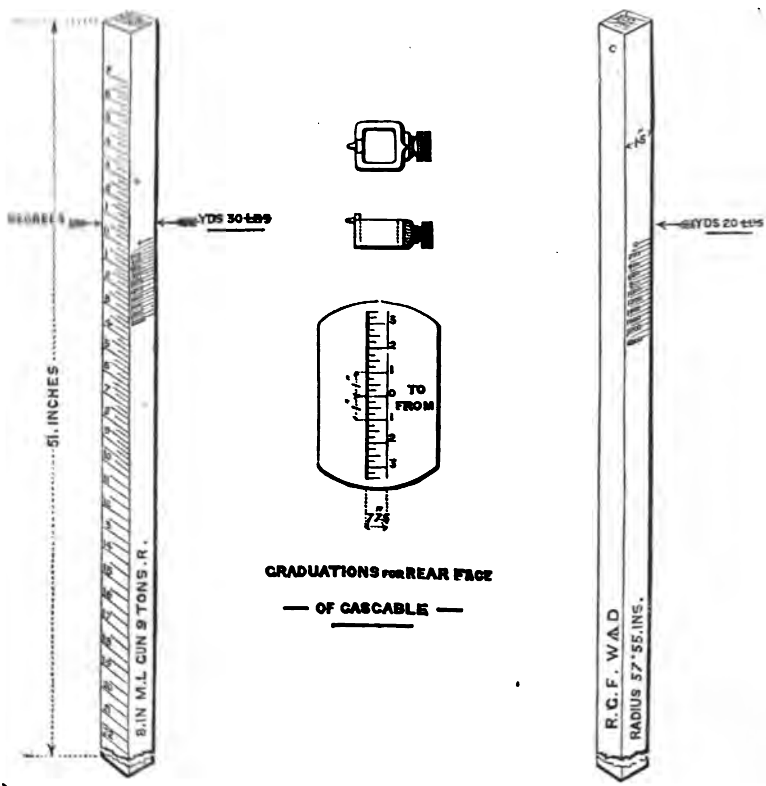
The slow motion elevating screw in tangent sights for land service (see page 70) is abolished in sights for guns of 64-pr. calibre and upwards; so that land service and sea service sights for guns of these natures will in future be interchangeable.

The depth of notch of all sights for guns of 64-pr. calibre and upwards will in future be 0·15-inch, in lieu of 0·06 inch as heretofore. The sights are so arranged that in laying the gun the apex of the fore-sight will be brought clearly into view, by taking what is termed a "half-sight."

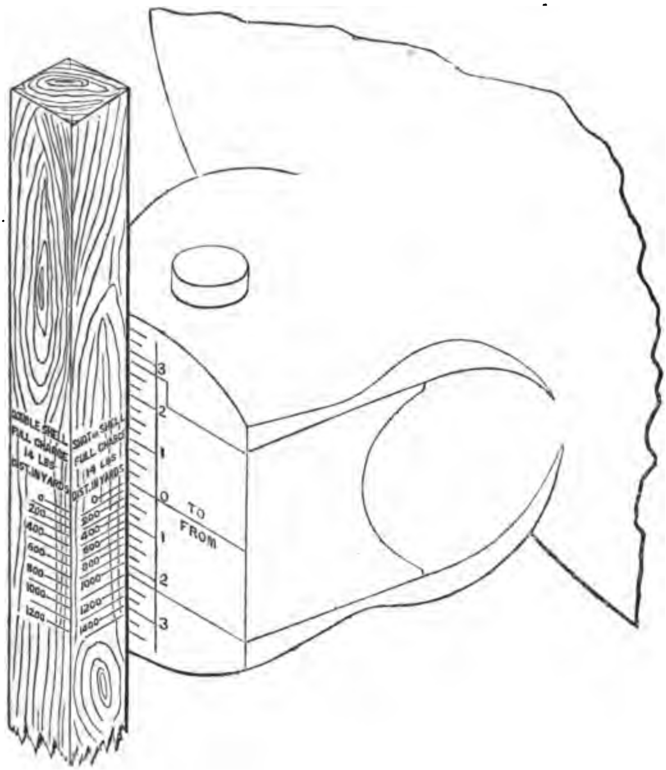
Trunnion and centre fore-sights.

The trunnion sights and centre fore sight are of the "drop" pattern described at page 73.

Wood Scale (8-inch R.M.L. gun).
Scale $\frac{1}{8}$.



MANNER IN WHICH THE WOOD SCALE IS USED.*



For naval service a *wood scale* is used in connexion with the ship's pendulum, for giving elevation or depression when the object aimed at cannot be seen from the gun. The scale is square in section, and is graduated for degrees and yards, both for full and battering charges. **Wood scale.**

In order readily to distinguish the yard scales from one another, the top of the scale is painted as follows, viz.: for battering charges, red; for full charges, white; for double shell (7 inch only), blue.

When it arrives on board, it is cut so that when placed upright on the naval slide, the zero of the scale corresponds to the zero of the graduations ($3\frac{1}{2}°$ elevation or depression), on the rear face of the cascable, the gun being parallel to the deck. It is provided with a moveable slide, fitted with a pointer and clamping screw; this can be set at the required elevation or depression, and must be made to coincide with the degree on the cascable, which corresponds with the heel of the ship, in order to give the necessary elevation to the gun (see Changes in Patterns, §§ 1477–8). **Adjustment.**

The graduations on this scale are computed with a radius equal to distance between the rear face of cascable and the axis of the trunnions.

When the radius is above 40 inches the graduations on the tangent scales are calculated for each degree, and therefore increase in length for the higher elevations. Under 40 inches radius the scale is calculated for the highest elevation and divided into degrees of equal length.

When guns are mounted in turrets the sighting arrangements are special for each ship. The direction is given by sights on the top of **Turret sights.**

* The scale shown in this drawing is not fitted with the moveable slide and clamping screw used in the latest patterns, which is shown in the preceding woodcut.

the turret which traverses with the gun, and the elevation is given to the gun either by means of the wood scale, or else by a pointer attached to one of the trunnions and moving over a graduated arc on the side of the carriage.

Guns mounted on Moncreiff carriages are fitted with special reflecting sights (in addition to the ordinary sight) by means of which the gun can be laid without exposing any of the detachment. They are fitted in the R.G.F., and the holes bored for the purpose are filled with preserving screws for transport, &c. Instructions for adjustment on service are given at page 190.

Operation of venting with copper.

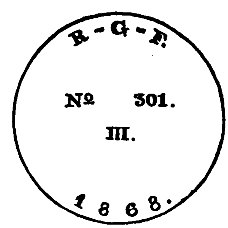
(5.) The drilling of the hole for the copper cone bush is performed by means of the radial machine, after which it is tapped, &c. by hand, as in the case of smooth bored ordnance, and the bush is treated in the same manner, the letter H being stamped on the top to denote that it is of hardened copper (see page 134).

Marking.

(6.) In addition to the *marks* made in lining, and the Royal cypher before mentioned, the broad arrow and actual weight are stamped in front of the vent, and two parallel lines are cut across the vent field to indicate the unrifled space. Similar lines are also engraved on the top of guns of 8-inch calibre and upwards to denote the position of the centre of gravity and the point at which the sling must be placed in order to take half the weight, the gun being at the same time slung at the cascable.*

The material of the inner barrel (for example FIRTH'S STEEL) is stamped on the face of the muzzle, as is also the number of the steel barrel as entered in the registry of manufacture.

On the left trunnion are—the initials R.G.F., the register number of the gun, the numeral signifying its pattern, and the year of proof. The register number is that by which the gun is registered in the department records; it indicates also the number of that nature manufactured.



Adjustment of fittings.

(7.) The extra fittings for R.M.L. guns are gun-metal elevating plates for guns for both services, guide-plates and friction tube pins for sea service, and muzzle studs and shot bearers for land service.†

Elevating plates.

The position of the *gun-metal plates* for the elevating racks being measured from the "lines" already marked on the gun, and the holes being drilled and tapped by hand, the plates are firmly attached to the gun by means of a screw at each corner. They are also marked with the number of gun to which they have been adjusted.

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* See § 1936, List of Changes, 1st September 1870.

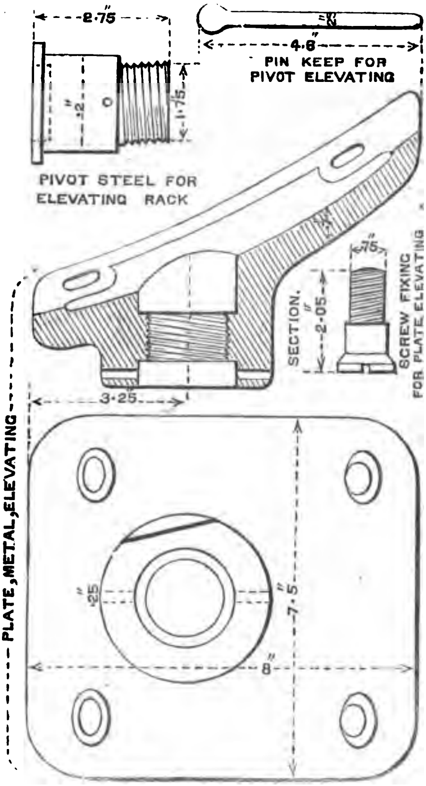
Only 8-inch guns and upwards are marked with the lines indicating centre of gravity and half weight; and as some of the following natures have been issued without these lines the respective distances are given :—

Nature of Gun.	Distance of Centre of Gravity from Muzzle.	Distance of Half Weight from Muzzle.
	"	"
8" M.L. guns, 9 tons, Mark I.	86·45	36·4
" " Mark II.	87·85	39·2
" " Mark III.	87·75	39·0
9" M.L. guns, 12 tons, Mark I.	90·55	34·1
" " Mark II.	90·5	34·0
" " Mark III.	90·9	34·8
" " Mark IV.	90·55	34·1
" " Mark V.	90·585	34·17
10" M.L. guns, 18 tons, Mark I.	109·75	49·5
" " Mark II.	109·55	48·35

† The flash from the inclined vent of 10-inch guns, when mounted on low slides on gun-boats, having been found liable to injure the detachment, a gun-metal *flash-pan* is fitted to these guns when so mounted.

DETAILS OF PIVOT PIECE FOR ELEVATING RACKS, 9-IN. R.M.L. GUNS, 12 TONS.

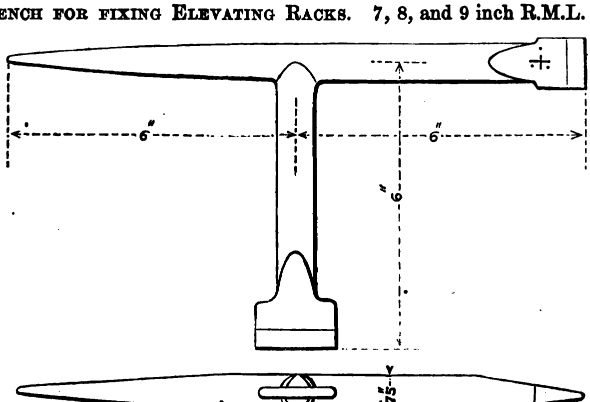
See § 1435.



Scale ½ size.

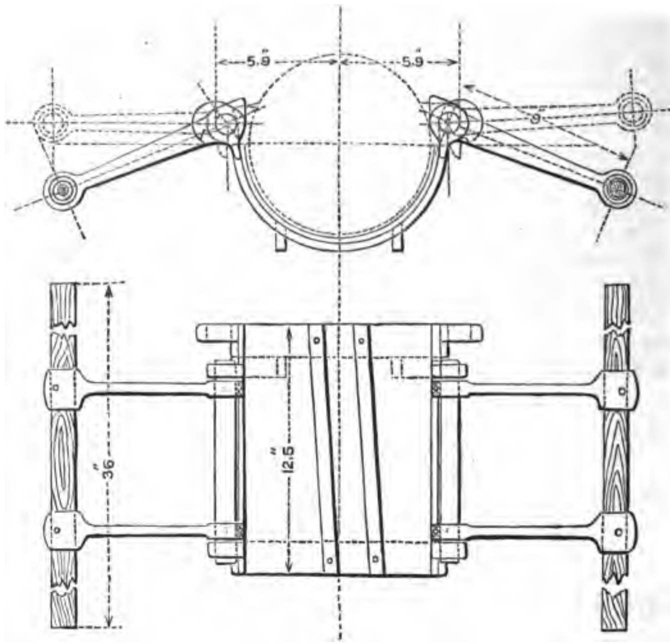
These plates are right and left handed, and consist of the following parts: a metal plate, steel pivot for elevating rack, keep-pin for pivot, and four screws for fixing the plate. They serve to connect the gun to the elevating racks on the carriage; they are attached to the guns by means of a wrench.

WRENCH FOR FIXING ELEVATING RACKS. 7, 8, and 9 inch R.M.L. Guns.

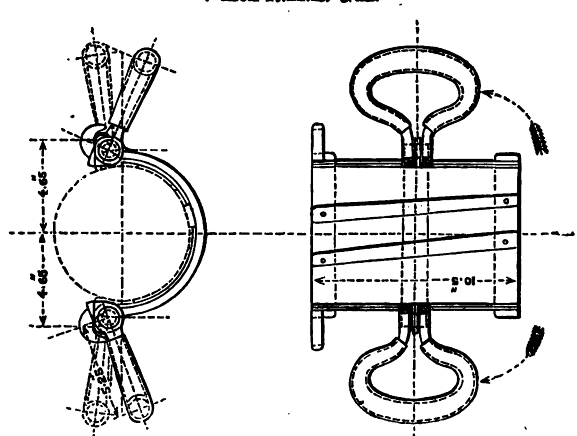


Friction tube pin. *The friction tube pin* is screwed in 1·3 inch to the left front of the vent (see page 99), and a spare hole is made adjoining it, lest the pin should be broken off, leaving its stump in the first hole. The leather loop of the S.S. quill friction tube is placed over this pin, to prevent the tube coming out or breaking when the lanyard is pulled, whilst to ensure direct action, the lanyard is passed through the *guide-plate*, which is screwed into the gun in rear.

SHOT BEARERS, L.S. 9-inch R.M.L. Gun.



7-inch R.M.L. Gun.



§ 2207. The hooks on the shot bearers shown in cut have been removed. The handles of the 9-inch are now made of iron tubing.

Studs to support the shot-bearer have been hitherto screwed into the muzzle of heavy guns before issue.

A pulley arrangement is used for loading in the naval service, so shot bearers, and studs to rest them on, are not required, and by an order dated 12th Oct. 1871, 9-inch guns and upwards will in future be loaded in a similar manner on land service. Muzzle studs have also been found unnecessary with the 7 inch and 8 inch gun. They have consequently been abolished for all guns (10th November 1871), and those already prepared for them will in future be fitted with preserving screws as has heretofore been the case when issued for sea service. § 2111. Preserving screws.

L.S. guns are also drilled and tapped for the guide plate and friction tube pin, the holes being filled by preserving screws: thus these guns can be made available for sea service should occasion require.

The preserving screws in the friction tube pin holes answer the purpose also of indicating the position of the vent by the touch, during night firing.

To bring the *cascable* to the approved shape, its sides are sloped towards the rear. Shaping the cascable and scoring.

To prevent the handspikes slipping when working the gun, the breech is *scored* underneath at each side and at the end.

(8.) The exterior of the gun being well cleaned, receives one coat of "Pulford's magnetic paint," which is now used for all iron guns instead of anti-corrosion, to which it is superior in point of cheapness and durability. The bore receives one coat of the usual lacquer. Painting and lacquering.

Finally. The gun with all its fittings having been inspected, and found in exact accordance with the sealed pattern, is issued for service.

CHAPTER VIII.

MANUFACTURE OF WROUGHT-IRON AND STEEL RIFLED M.L. GUNS FOR FIELD, SIEGE, MOUNTAIN, AND BOAT SERVICES.

The 64-pr. R.M.L. Gun, Mark III.—Construction.—Coiled Barrels.—"Shunt" Rifling, and objections to it.—Plain groove Rifling.—Sighting, Venting, &c.—*The 40-pr. R.M.L. Gun, Mark I.*—Construction.—Rifling, plain groove—Venting.—Sighting.—*The 16-pr. R.M.L. Gun, Mark I.*—Construction.—Rifling.—Venting.—Sighting, &c.—*The 9-pr. R.M.L. Gun, 8 cwt., Mark I., and 6 cwt., Mark I.*—Construction.—Rifling.—Sighting.—Venting, &c.—*The 7-pr. R.M.L. Gun, Mark III. (Steel).*—Rifling.—Venting.—Sighting, &c.—All guns fitted for Sea service.

The 64-pr. Rifled M.L. Gun. Mark III.

The construction of this gun is similar to that of the 7-inch gun, Mark III., already described, the jacket consists of a double coil, a trunnion-ring, and a single coil welded together. Construction.

Guns of this nature made since April 1871 have solid ended steel tubes and a B tube shrunk over the chase. Previous to that date, however, the whole of the 64-prs. had coiled iron barrels, which in this pattern of gun was made double at the muzzle end, so as to obviate the necessity for shrinking on a B tube. Steel barrel.

Coiled barrel. The coiled barrel is made as described for the 40-pr. B.L. gun (see page 58), but the two coils used for the muzzle end are double. The

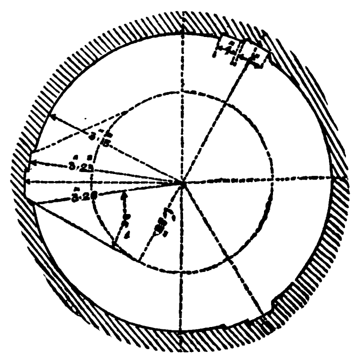
Method of closing breech end of barrel. breech end of the chamber is made slightly conical, and the tube closed by what is called the "Elswick loose end" (see plate). This consists of a wrought-iron plug which fits tightly into the end of the tube, and against a shoulder which is shaped so that the pressure of the gas tends to close it out against the plug and thus prevent any escape. Behind this plug is placed a copper disc 0″·25 thick, fitting into a recess in the end of the barrel, and against this is screwed a wrought-iron cascable similar to that used for the heavy guns.

The copper disc is intended to act as a cushion or buffer between the plug and the cascable, and, by absorbing some of the force of the blow, to prevent the former from being injured. There is the usual gas escape cut through the cascable screw (see page 132).

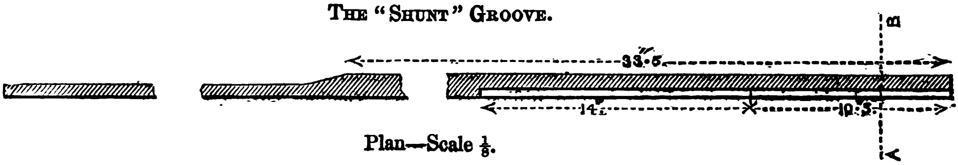
Rifling. § 1032. §§ 1752, 1996. Prior to January 1871 the whole of the 64-pr. W.I. guns were rifled on Sir W. G. Armstrong's "Shunt" system; all guns made since that date and all old guns on being re-tubed are, however, rifled with the plain groove adopted in 1868 for the converted 64-prs.

The Shunt rifling will therefore be gradually abolished, but a large number of guns in the service still retain it.

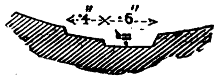
Plan of Muzzle showing "Shunt" Grooves. Scale 3 ins. = 1 foot.



The "Shunt" Groove.



Plan—Scale $\frac{1}{8}$.



Section on AB. Scale $\frac{1}{2}$.

"Shunt" system. The peculiarity in this system of rifling is that the depth and width of the grooves varies at different parts, the object aimed at being to provide a deep groove for the studs of the projectile to travel down when the gun is being loaded, and a shallow groove through which they must pass when the gun is fired, so that the projectile may be gripped and perfectly centred on leaving the muzzle. This is attained by making one side of the groove (the driving side) near the muzzle shallow, as shown above, the unshaded portion representing the shal-

low part or grip. The projectiles have soft copper studs, which fit easily with a windage of 0″·025 into the deep portion of the groove; when the gun is loaded the studs travel down this deep portion until they arrive at 33″·5 from the muzzle, where they meet with an incline, by which they are "shunted" into a narrower part of the groove (still of the same depth) down which they travel to the chamber.

On discharge the studs bear against the other side of the groove, until at 24″·5 from the muzzle they come to an incline upwards 14″ long, up which they travel, the studs being thereby compressed 0″·005. With this compression they pass out through the remaining 10″·5 of the bore. Action.

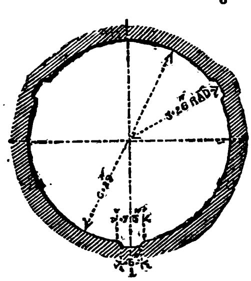
There are three grooves with a uniform pitch of one turn in 40 calibres, the edges being angular.

In the bottom groove at the extremity of the rifling there is an additional shunt, the object of which is to bring the studs well up against the driving edge of the grooves, and thus to reduce their liability to being sheared by the shock of discharge.

The objections which have led to the abandonment of this system of rifling are (1.) It is complicated. (2.) It is not found to answer well in practice. (3.) The projectile is gripped at the muzzle when at its highest velocity. (4.) The sharp angles at the edge of the grooves renders the tube liable to split. Objections to shunt rifling.

On examining projectiles which have been fired it is found that the centring action does not truly take place, as the greater part of the compression is taken by one row of studs. Moreover the studs are found to be worn in steps, showing that they have overridden the grooves into the lands, owing to the small bearing surface on the driving side of the grooves near the muzzle. This would account for the inferior shooting of these guns, compared with those rifled with the plain groove, by which the shunt has been superseded.

Plain Groove. Scale $\frac{1}{8}$th.



This is really the narrow deep portion of the groove continued to the muzzle without the shunt or incline. It is 0″·6 broad at the bottom and 0″·11 deep, with angular edges, the corners being slightly rounded off. The number of grooves and pitch of rifling are the same as in shunt guns, and this groove has been adopted in order that the shunt ammunition may be fired from all 64-prs. in the service, thus simplifying the issue of ammunition. Plain groove rifling.

The lining, sighting, and venting, and the stores for these guns, are similar to those for the heavy guns, except that they have no elevating plates, shot bearers or studs. Sighting, venting, &c.

The 40-pr. Rifled M.L. Gun of 35 cwt. Mark I. (Experimental.)

The construction of this gun is identical with that of the heavier natures, Mark III., but the jacket consists of two single coils and a Construction.

trunnion-ring welded together. The steel tube is solid ended, and is supported at the breech by a cascable screw, through the thread of which there is the usual gas escape.

Rifling. The calibre of this gun is 4″·75, and it has the plain groove rifling, but the grooves are only 0″·8 in width at top and 0″·1 in depth. They are three in number, with a uniform spiral of one turn in 35 calibres.

Venting. It is vented with a hardened copper cone vent, so as to strike the curve at the bottom of the bore, both to ensure that the whole of the unconsumed portion of the cartridge may be blown out, and also for the purpose of firing very reduced charges.

Sighting. It is side-sighted, having two tangent sights and screw trunnion sights of the usual pattern, the tangent sights being inclined at an angle of to the left.

The 25-pr. Rifled M.L. Gun of 22 Cwt. Mark I. (Experimental.)

Construction. The construction of this gun is the same as the 40-pr., but without the cascable screw, the solid end of the A tube projecting beyond the breech of the jacket so as to form the cascable.

Rifling. The calibre is 4″ and the gun is rifled with three plain grooves of the same shape, dimensions, and twist as the 40-pr.

Venting. It is vented with hardened copper in the same position and for the same reasons as the 40-pr.

Sights, &c. Same as the 40-pr.

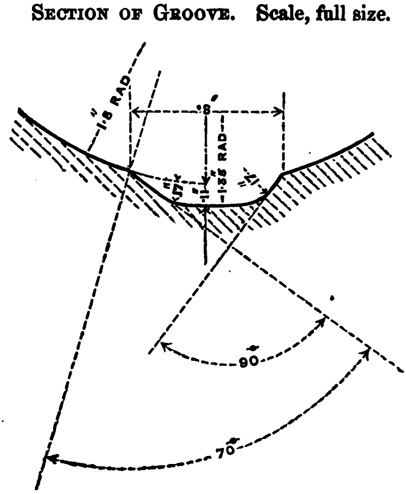
The 16-pr. Rifled M.L. Gun of 12 cwt., L.S. Mark I.

Construction, &c. &c. This gun consists of two parts only, viz., a toughened steel tube, and a jacket, composed of two single coils and a trunnion-ring welded together.

The cascable is cut out of the solid end of the steel tube, as in the 25-pr., and the chase of the gun for a distance of 30½ inches from the muzzle is entirely of steel, the tube being thicker at that part.

Rifling. The calibre is 3″·6, and the gun is rifled with three grooves on the modified French system with a twist of one turn in 30 calibres. (See fig.)

SECTION OF GROOVE. Scale, full size.



The driving edge of the groove forms an angle of 70° with the normal to the surface of the bore, and the loading side is at right angles to the driving side.

The width is 0″·8 at top, and the depth 0″·11; the bottom of the groove being eccentric to the bore, and the corners rounded off.

The object aimed at in this form of groove is that the studs may run up the incline on the driving side and thus be gripped and the projectile centred, this centring action being also assisted by the curvature of the bottom of the groove.

It is vented with hardened copper in the same position and for the same reasons as the 40-pr. Venting.

This gun is side-sighted only, having two tangent sights set at an angle of 1°·50″ to the left, and two steel trunnion sights screwed in. Sighting.

The tangent sights have rectangular steel bars with gun-metal sliding leaf heads, and are graduated with degree, yard, and fuze scales. On account of the short radius of sighting the slow motion elevating nut is retained in order to obtain the required accuracy of aim.

The 9-pr. Rifled M.L. Gun of 8 cwt., L.S. and S.S. Mark I.

This gun is identical in construction with the 16-pr., except that there is a swell at the muzzle and a dispart patch (see Plate I.). This swell is cut out of the solid steel, except in a few of the guns first made, in which it consists of a wrought-iron ring screwed on. These can be known by the small fillet which runs round the chase where the iron ring ends. Construction, &c.

The calibre is 3″, and the rifling is the same as in the 16-pr. It has three grooves, with a uniform pitch of one turn in 30 calibres. The venting is the same as in the 16-pr. Rifling. Venting.

It is sighted centrally. The tangent scale works in a gun-metal socket let into the breech of the gun at an angle of 1° 30′, and there is a recess into which the head enters, so that it may be protected from injury. Sighting.

The fore-sight is a small hog-backed sight screwed into a recess in the dispart patch, so that it is also protected from accidental injury.

The tangent sight consists of a small rectangular steel bar, with a steel head and gun-metal sliding leaf, the latter being clamped by a thumbscrew to the rear or breech side, unlike the sights for heavy guns. It is graduated to 6°, each degree being subdivided into 20 divisions of 3′ each; the radius being the whole length of the gun, the length of a degree on the tangent scale is sufficient to allow of its being thus subdivided. The length of a tangent scale for 6° is equal to the thickness of metal at the breech, but for higher elevations there is a second tangent scale graduated to 12°. Both sights are clamped by means of a gun-metal thumbscrew. Sights.

There is a deflection scale on each sight, graduated to 30′.

There is a brass plate fastened on the right side of the trail, showing the ranges in yards and lengths of fuze, the tangent bar being only graduated in degrees. § 2197.

Spare dispart sights are issued rough, in case the sight in the gun should get broken, and a wrench is supplied for removing and replacing it. To fit the new one it will be necessary to level the gun longitudinally along the bore, and to screw the rough sight home into the dispart patch, bringing its leaf parallel to the axis. Then file the top down until it is level with the notch on the tangent sight, measure the radius (66″) also from the back of the tangent sight, and file the back and front slopes. With a rule or straight-edge mark the centre line on Resighting on service.

the top of the leaf opposite the line of vertical axis engraved on the dispart patch and muzzle of the gun, and file up the front side slopes to this line. Remove the sight from the gun, rough the back slope, clean and blue it (as described at page 188), and replace it in the gun in the same position.

It is vented the same as the 16-pr.

Cascable. The cascable is recessed to receive the head of the elevating screw, which is fastened to it by a wrought-iron bolt, both secured with a steel keep-pin.

The engraving and marking of the gun is the same as for other natures.

The 9-pr. Rifled M.L. Gun of 6 cwt., S.S. Mark I.

Construction. This gun is identical in construction with the 16-pr., and differs from the 9-pr. of 8 cwt. only in weight and length, and in having no swell at the muzzle (see Plate I.).

Rifling, &c. Venting. It is rifled with the same groove and pitch as the 8 cwt. gun, in order to fire the same ammunition. It is also vented in the same manner.

Sighting and sights. Being intended for boat service it is sighted exceptionally.

The tangent sight consists of a plain rectangular steel bar, without any deflection arrangement, the head being high enough to clear the quill friction tube when in the gun. It works in a gun-metal socket let into the breech of the gun at an angle of 1° 30′ to the left.

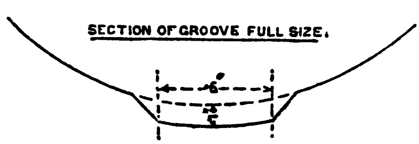
The dispart sight is of steel, in form like the Millar's foresight used with cast-iron S.B. guns, and is fastened to the muzzle of the gun by three screws. If damaged a new muzzle sight can be adjusted to this gun in a similar manner as with the 8 cwt. gun.

Cascable. The cascable is recessed for the head of the elevating screw, to which it is fastened by a bolt.

The 7-pr. Rifled M.L. Gun (steel) of 150 lbs. L.S. Mark III.

Manufacture. This gun is made out of a solid block of steel (see Plate I.), rough bored and shaped, then toughened in oil, and afterwards finished in the usual manner.

Rifling, &c. The bore is 3″, and it is rifled with three grooves on the "French" system, having a twist of one turn in 20 calibres.



This rifling differs from the modified French system (used in the 9-pr. and 16-pr.) in not having the corners rounded and in the curve of the bottom of the groove being described concentric to the bore. The grooves are 0″·6 wide at the bottom and 0″·1 deep.*

Venting. The gun is vented with a hardened copper cone vent, 18 threads to the inch, so placed that the vent channel shall strike the cartridge 1″·0 from the end of the bore.

Sighting and sights. It is sighted centrally only.

The tangent sight works in a gun-metal socket let into the breech of the gun at an angle of 3°, and is clamped by a gun-metal thumbscrew on the right side of the socket.

* This is the only groove in the service in which the width is measured at the bottom, the angles being rounded off in all other grooves the width at bottom cannot be accurately measured.

The ordinary tangent scale is of steel, with a plain head and no deflection arrangement. It is graduated to 12°, but for higher elevations a similar scale, made of walnut wood and graduated to 20°, is supplied.

The dispart sight is on the muzzle, and is cut out of the solid steel.

The cascable is fitted underneath with a bearing for the head of the elevating screw, and has a hole 2″ in diameter through it from side to side, in order that a bar or rod may be passed through to facilitate transport on men's shoulders over very difficult positions. Cascable.

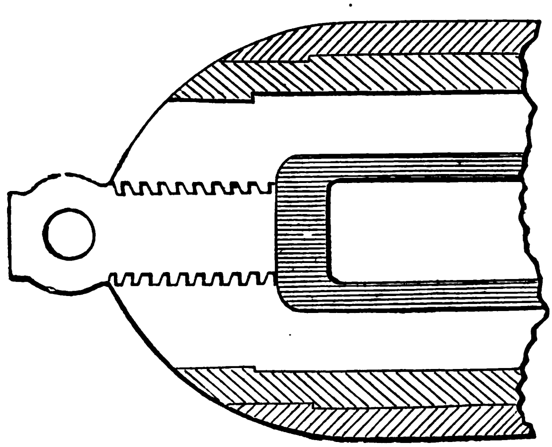
Note.—The whole of the foregoing guns, from the 64-pr. to the 7-pr., are marked in the usual manner, and are fitted for both land and sea service (except the 16-pr. and 7-pr. steel gun), so that when issued for the former service the holes for the friction tube pin and guide-plate are filled with preserving screws. All guns fitted for sea service.

CHAPTER IX.

GENERAL REMARKS APPLICABLE TO WROUGHT-IRON RIFLED M.L. GUNS.

Exterior form of Original and present Construction.—*Gas Channel or Escape Hole.*—Lines on Guns.—*Vents and Venting.*—Position of Vent.—Various kinds of Vent Bushes.—Manufacture of "Hardened Copper Bushes."—*Re-venting on underside.*—Use of Wads.—Thickness of Steel Tubes.

Exterior Form.



Breech rounded.

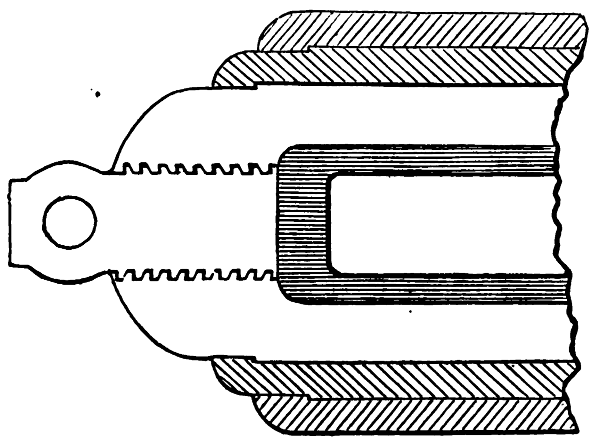
Mark I. 64-pr., 7-inch, 8-inch, and 9-inch.—Are rounded off at the breech, because at the time of their introduction the breeching rope was used through the breeching loop, which was provided with a moveable block and pin, and consequently this shape of breech was Original construction.

adopted to save the rope from wear. They have also several steps in front of the trunnions.

Mark I. 12-inch and 13-inch are stepped at the breech.

Fraser modification, with solid forged breech-piece. §§ 1334, 1335.

Mark II. 64-pr., 7-inch, 8-inch, and 9-inch.—The curve at the breech is broken by the breech-piece which forms a step; the breeching rope being carried through the carriage, the moveable block in the breeching loop was abolished, and the thin edges of the layers of coil caused by the rounded outline was considered objectionable owing to the liability of the edges setting up. This and all future patterns have but one step in front of the trunnions.



Breech cut in Steps.

Fraser modification, with one layer.

Mark III. 64-pr., 7-inch, 8-inch, and 9-inch, and Mark I. 10-inch and 11-inch.—Having but one layer at the breech it is rounded off.

Fraser modification, with two layers.

Marks IV. and V. 9-inch, and Mark II. 10-inch, 11-inch, and 12-inch.—As a rounded outline in this pattern would introduce the objectionable thin edge, the breech is cut in steps, corresponding to the layers of coils.

Gas Channels or Escape Holes.

Gas channels.

The gas channel was introduced by Sir W. Armstrong in the first Rifled 600-pr. and the 150-pr. smooth-bored guns having coiled barrels and Elswick loose ends; the object was to permit the escape of any powder gas that might have found its way behind the plug and so render the breech liable to be blown off, as the gas would then act on a larger area and have at the same time less metal to resist it. In 1865 it was adopted for guns having *steel* barrels, so that in the event of the tube splitting in the vicinity of the chamber, the gas escaping through the channel would indicate the fact to the detachment at the gun, *and firing should immediately cease* (see page 110).

O.S.C. Proceedings, 1867, p. 100.

The importance of watching this gas channel cannot be overrated, for, in 1867, whilst experiments were being carried on with a 13-inch gun, "at the round immediately preceding that when the gun failed "there was a considerable escape of gas from it (the channel), and "being observed every precaution was taken in firing the next round, "which proved to be the last." The tube of an 8-inch gun was also

discovered to have failed at proof, simply by watching the gas escape without any further examination.

A simple plan is to place a small screw of paper in the escape, for should the tube fail the paper will be blackened by the gas.

Mark I. 64-pr., Wrought-iron Gun. — Has no gas escape, being manufactured before its introduction, but any of this pattern that may require retubing will receive it.

Mark I. 7-inch, 8-inch, 9-inch, and 12-inch.—A hole 0″·3 diameter was drilled through the breech-piece, at right angles to the cascable screw, so as to meet the annular space on the cascable, a groove also being cut along the outer edge of the breech-piece so as to meet this hole. In this pattern the gas escape comes out *underneath* the cascable, between the breech-piece and the coil overlapping it.

Other patterns. See page 110.

Lines.

Two lines are marked on the upper surface of all the R.M.L. guns, that in front of the vent denotes the **end of the rifling,** the other in rear of the vent **the end of the bore.** These lines are useful to enable the sponge or rammer staves to be marked at the exact distance from the muzzle to the end of bore or rifling. § 1562.

Guns over 7-inch calibre have also lines marked on the top, one showing the **centre of gravity,** and the other on the chase showing where the **sling** is to be placed, the gun being at the same time slung by the cascable. § 1936.

The **vertical line** on the right trunnion enables the gun to be laid point blank (or brought horizontal) at any time without the aid of sights.

The **horizontal line** on the right trunnion is for use when firing at angles of *depression*. These angles may be shown upon the carriage by lines marked from the edge of the trunnion hole. § 2.

The two latter lines are not marked on light field guns, being unnecessary.

The lines on *muzzle* and *breech* are for adjusting the sights and elevating plates (see page 114).

Vents and Venting.

Venting. O.S.C. Proceedings, 1863, p. 154.

In 1863 General (then Colonel) Lefroy submitted that "the time had "come when it was desirable to consider whether the habitual practice "of igniting the charge at the back end is favourable for developing "the greatest force of the charge with the least strain on the gun, the "elongated charges coming into use with the heavy shot and powder "of larger grain than formerly having altered the old conditions."

Experiments to ascertain the best position for vent. O.S.C. Proceedings, 1863, p. 394; 1864, p. 66.

Experiments were then sanctioned to be carried out in a bronze gun of 6″·5 calibre bored up to 6″·9. It was vented in six different positions, viz.:—

No. 1. Came out exactly at the base of the charge.
„ 2. Half-way between that and the service vent.
„ 3. Service vent.
„ 4, 5, and 6, respectively, 1″·38, 2″·76, and 4″·25 in front of true vent.

With 14 lbs. charge R.L.G. powder and 42-lb. shot, the following mean initial velocities were obtained from the above-mentioned vents:—

	1st Experiment.	2nd Experiment.
	Feet.	Feet.
No. 1 vent - -	1,773	—
„ 2 „ - -	1,782	—
„ 3 „ - -	1,789	1,794
„ 4 „ - -	1,816	1,836
„ 5 „ - -	1,861	1,895
„ 6 „ - -	1,811	1,860

"It is observed that the velocity increased as far as the 5th vent, the "greatest increase being from the 4th to the 5th, at which point the mean "initial velocity was increased 72 feet per second above what had been "obtained when using the service or No. 3 vent. In proceeding to No. 6 "vent the velocity was suddenly diminished 51 feet per second." These experiments were repeated, but the difference between Nos. 3 and 5 was still greater, being now 100 feet per second. "Taking the "mean between the two results, viz., an increase of 86·5, it is equivalent "to an increase of the charge from 14 lbs. to 15½ lbs., and in the "opinion of the committee proves conclusively that the vents of guns "using heavy charges should be bored so as to strike the cartridge in "the position of No. 5 vent, that is to say, at about $\frac{4}{10}$ths of its length "from the end of the gun, or slightly behind the centre of the car- "tridge. The committee recommend that the position of the vent "in all future wrought-iron M.L. guns, be such as to fulfil this condition, "and that the vent be drilled vertically as already adopted by Sir "W. Armstrong in all his larger guns."

Recommended vertical vents to strike cartridge $\frac{4}{10}$ths of its length from end of bore.

Approved, § 900.

Both of these recommendations were approved 14/4/64, as the experiments had proved that the ignition of the cartridge at the point above-named "realizes the greatest projectile force which can be pro- "duced by a given charge."

No account was taken in these experiments of the pressure in the bore, which has since been proved to be much greater when charges of R.L.G. powder are fired with the forward vent.

In the undermentioned wrought-iron guns the vent strikes the cartridge as follows, the distance being from the end of the bore :—

	64-prs. I.	64-prs. II. & III.	7″	8″	9″	10″	11″	12″ 25 tons	12″ 35 tons.
Inches	6·1	5·2	8·6	9·2	9·7	11	10	9·8	12

In other natures the vent strikes the cartridge near the end of the bore.

Vent bushes.

Compound bushes tried.

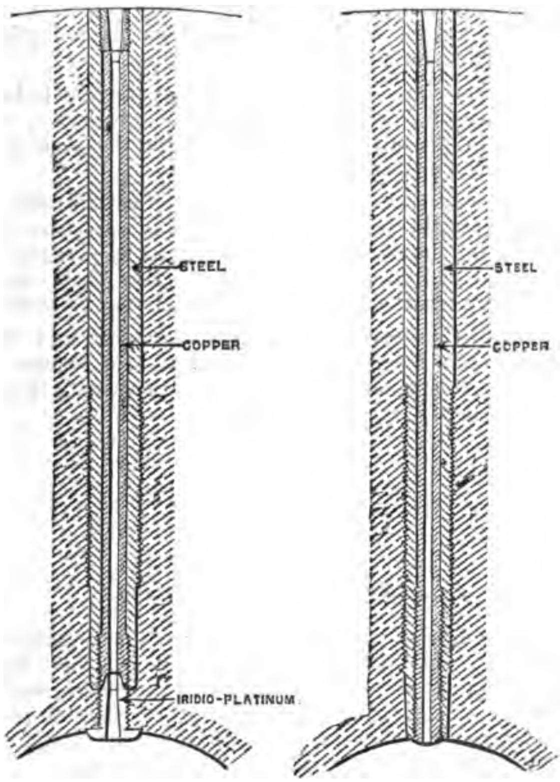
§ 1688.

Up to 1st November 1868 the bushes used were the ordinary copper cone vents let in vertically, but at that period a new kind of vent (proposed by Major Palliser) was inserted in the 10-inch guns required for H.M.S. "Hercules." It consisted of a steel bush lined with copper, screwed in from the exterior against a platinum tip screwed up from the interior, the tip having a flange or button-shaped head projecting into the bore to close the joint; but instead of entering the bore vertically, it was fixed upon the side of the gun at an angle of 45° to the vertical axis in order that it might be more easily served.

It was subsequently decided, 25th November 1868, that all wrought-iron guns of 7-inch calibre and upwards should have similar vents (Fig. I.), but let in vertically as before, except in the case of 10-inch guns, whose size would render the vertical position awkward. § 1718.

Scale $\frac{1}{2}$ size.

Fig. I. Fig. II.



The latter position was approved, 28th September 1869, for all guns of 18 tons and upwards; if required for a garrison or broadside gun it is the right side, but if intended for a turret gun, the vent is placed on the right or left hand side as convenience demands.

This nature of vent was tried for a short time, but not proving satisfactory the platinum tip was suspended, and steel vents lined with copper (Fig. II.) were used; but as these also did not answer expectations, all rifled M.L. guns are now cone vented with copper specially hardened, § 1821. the letter H being stamped on the top to indicate the fact.

Hardened copper bushes.

The copper is 2 inches square in section. It is drawn down square while cold under a light steam hammer to the size required for the screw, the blows being as light and numerous as possible, so that the greatest amount of condensation may be effected. It is afterwards turned to the proper dimensions and a seven thread screw cut on it.

Through vent.

There are two kinds of copper bushes, namely the "through vent" and the "cone vent." The through vent is a cylinder $1\frac{1}{8}$ inch in diameter, cut with a screw thread $\frac{1}{16}$ inch deep, and having a square head by means of which the bush is screwed into the gun.

Cone vent. A "cone vent" is of the same shape and size as a "through vent," except near the end where the screw thread terminates, and the cylinder merges into the frustum of a cone 1¼ inch in length, and ⅞ inch in diameter at the extreme end. All guns are first vented with a cone vent, and a through vent is only used when the wear round the copper is so great that the cone will not remove the whole of it.

§ 1812. In 18 ton guns and upwards the threads are limited to a length of 6 inches above the cone, the upper part being plain. Guns for sea service have the mouth of the vent rimed out to a depth of 1 inch, tapering from ·28 at the top to ·22 at the bottom.

§ 1821. It is directed that rifled ordnance are for the present to be re-vented only at certain stations,* as they require special tools, and no attempt should be made to perform this operation with the tools supplied for re-venting *cast-iron* ordnance.

Re-venting on under side. O.S.C. Proceedings, 1866, p. 86. The rush of gas in rifled M.L. guns causing considerable scoring on the upper portion of the bore over the projectile, a proposal was made in 1866 to prolong the duration of guns so damaged by plugging up the old vent, turning the gun over, and inserting a new bush. As the guns have their trunnions in the axis of the piece, this can be readily effected.

§ 1183. The proposal was approved, and all guns now passing † through the department on return from out-stations, should they require it, will be treated in the above manner, but it is not found necessary to do so until the gun has fired a large number of rounds.

A *tubes of all Rifled M.L. Guns.*

A tubes. In heavy guns having thin steel tubes (such as 9-inch, Mark IV.), the tube is of the same thickness throughout, but in those having thick tubes (12-inch 25 tons, Mark II., for instance) the muzzle end is thinner than the breech. The reasons for this are that the thick steel tube is not absolutely required to resist the reduced strain at that part of the gun, and by reducing it the B tube can be made stronger.

In some of the smaller natures (9-pr. and 16-pr.), in order to simplify manufacture, the muzzle end of the steel tube is made of sufficient thickness to form the chase of the gun without having a B tube shrunk over it. Steel unsupported by coiled iron is quite able to resist the comparatively slight strain to which it is subjected near the muzzle of these small guns.

Chambers. The form of the chamber varies in different patterns of heavy guns, that now used being slightly conical.

O.S.C. Proceedings, 1864, p. 291; 1867, p. 334. In the competitive 7-inch R.M.L. guns (*see* p. 14) tried in 1864–65, the end of the bore was hemispherical, which in a mechanical point of view is stronger than the flat end afterwards introduced into the service, which is to be found in all guns of the original construction.

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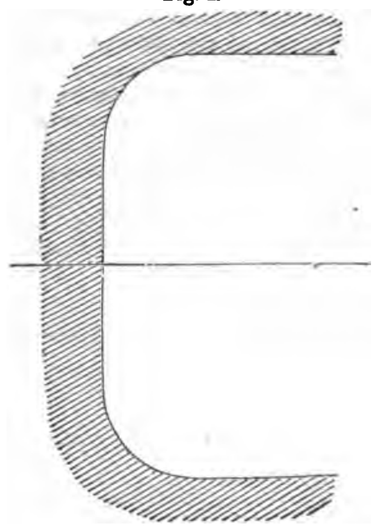
* Portsmouth, Devonport, Malta, Bermuda, Hongkong, and Esquimalt.

† Wads have also been used with a view to reduce the scoring. They have not, however, been quite satisfactory, and experiments are now (1872) in progress for the purpose of discovering a more efficient pattern, as the life of a heavy M.L. gun may be said to depend upon the amount of this scoring.

Form of Chamber in Guns of Original Construction. Scale ¼.

Fig. I.

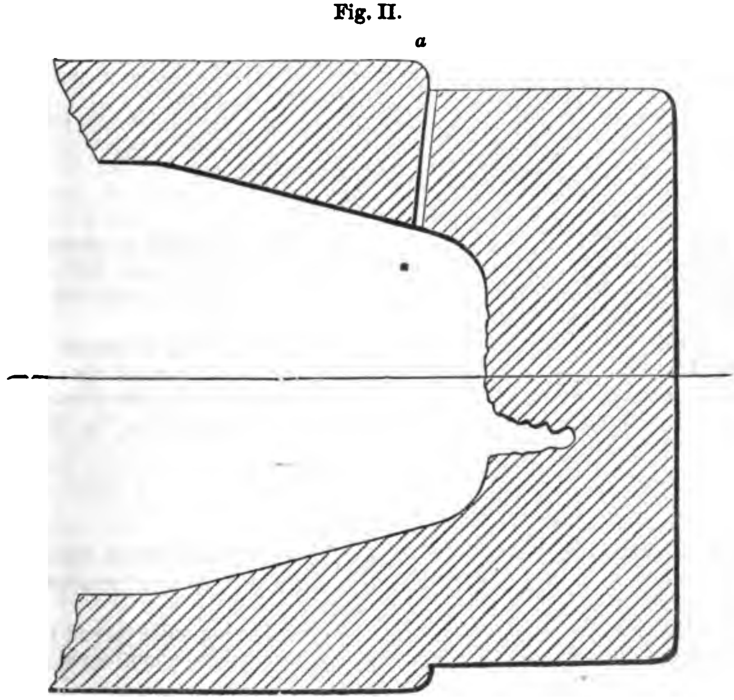


This hemispherical form was condemned on account of the rapid eating away of the metal at the end of the bore, which appears to be caused by the deflection of the gas upon this part from the sides of the chamber.

In the first guns constructed on the Fraser system a conical chamber was substituted for the flat-ended one then in use.

Chamber of 9-inch R.M.L. Gun. Exp[l]. No. 330. Scale ¼.

Fig. II.

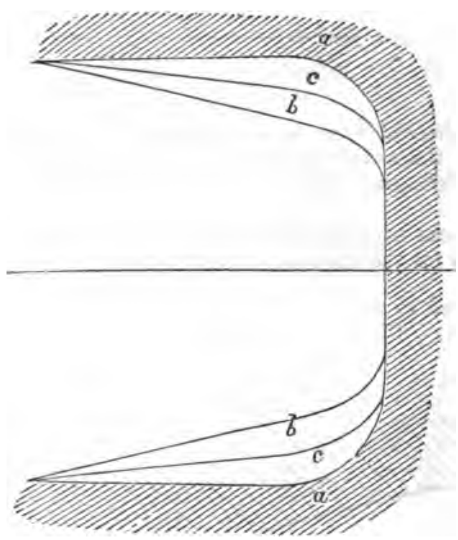


This form is necessary in order that the shoulder *a*, Fig. II., on the A tube may be enabled to take some of the longitudinal strain. If the metal at this point were not thicker than that of the rest of the tube it would break as easily there as at any other point, and the shoulder would become useless. By making the chamber conical a greater thickness of metal is left opposite the shoulder, consequently the line of least resistance is in front of it, and before the tube can break at its weakest point the strain is thrown upon the breech-piece by means of the shoulder.

The chamber in these experimental guns was coned to such an extent that the area of the bottom of the bore was reduced to half that of the bore of the gun (see *b*, fig. III.), but this was found to give rise to the same eating away of the metal at the end of the bore as was caused by the hemispherical chamber (see Fig. II.).

MODIFICATION OF CHAMBER IN PRESENT CONSTRUCTION OF GUNS. Scale ¼.

Fig. III.



For instance, in 9-inch R.M.L. gun, Expl. No. 330, a cavity three inches deep was found in the end of the tube after firing 500 rounds; and in 9-inch R.M.L. gun, Expl. No. 331, this defect was over two inches deep after the same number of rounds.

On this account the shape of the cone was modified as shown at *c* in Fig. III., and this is the form which is used in all guns of the present service construction; while guns of the original construction retain the flat-ended chamber with rounded corners, as shown at *a* in Fig. III.

Cascables.

Cascables. In small rifled M.L. guns below 40-prs., the cascable is formed by the end of the A tube; 40-prs. and upwards have a wrought-iron screwed in cascable.

In the original construction of heavy guns having solid forged breech-pieces the diameter of the cascable screw was made about equal to the

calibre of the gun (see Fig., page 132), thus affording a strong shoulder in the breech-piece against which the end of the A tube rests, thereby reducing the strain on the screw thread of the cascable.

In the present construction, the layer of iron next the tube being a coil, in order to retain the same diameter of cascable it would be necessary to make the interior of the whole coil much smaller than is now required, and afterwards to bore out a large portion of it for the reception of the steel tube. This would cause a considerable waste of labour and material, consequently in these guns the cascable screw is made nearly of the same diameter as the exterior of the tube, leaving only a small shoulder about half an inch broad. In order to get an additional bearing a second shoulder is cut on the tube about six inches from the end and about half an inch broad, as shown in the woodcut, page 137.

The object of this additional shoulder is to distribute the longitudinal strain over a larger portion of the coiled breech-piece.

CHAPTER X.

MANUFACTURE AND CONSTRUCTION OF CONVERTED GUNS.

Early experiments.—Guns proposed for conversion and those already completed on Major Palliser's system.—*Method of converting an 8-inch S.B. into a 64-pr. rifled gun.*—A tube.—B tube.—Method of fastening the tube in cast-iron casing.—*Venting.*—Proof and limits of expansion allowed.—*Sights and sighting.*—*Conversion of 32-prs. of 58 and 56 cwt.*—*Sighting, venting,* &c.—*Conversion of 68-prs. of 95 cwt.*—Rifling, sighting, &c.

METHODS OF STRENGTHENING CAST-IRON ORDNANCE.

As early as 1855 attempts were made to strengthen cast-iron guns by encasing them in rear of the trunnions with a wrought-iron jacket, and between that date and 1863 various plans were tried unsuccessfully. *Early experiments.*

In that year Captain (now Major) Palliser proposed to line cast-iron guns with coiled iron barrels, fitting comparatively loosely into the casing until expanded by the heavy proof rounds. This method appeared to be more promising than any previously tried, and was moreover founded upon correct principles, ***the stronger material being placed next the charge.*** *Palliser's system.*

Between 1863 and 1868 no less than 26 guns, converted on various plans proposed by Major Palliser, were tested at Shoeburyness, until in January of the latter year the Ordnance Select Committee (Report No. 4,888, Vol. VI., page 109) recommended the "extensive conversion for secondary purposes of defence" of certain cast-iron S.B. guns into rifled M.L. guns, by boring them out and inserting a coiled iron tube. This was approved and manufacture was immediately commenced, 212 8-inch guns being converted into 64-prs. at Elswick, and by the end of the present financial year (1871) the number of guns of this nature completed and ready for service will amount to about 1,100, including 50 guns for India.

The guns first converted were the 8-inch of 65 cwt., but the whole of that nature available having been completed, 200 32-prs. of 58 cwt. and 170 68-prs. of 95 cwt., are now being operated upon. The principles of conversion are identical in all cases, though the dimensions differ somewhat; we will therefore describe in detail the conversion of an 8-inch gun.

Guns proposed for conversion.

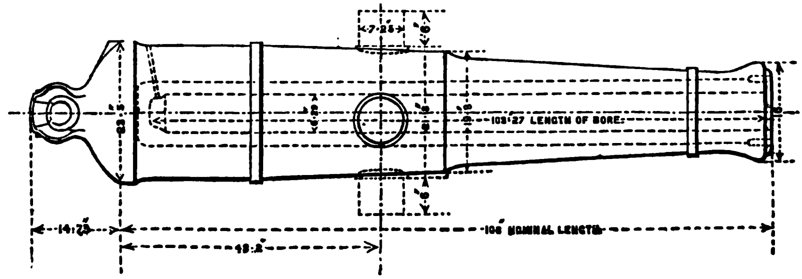
The following is a table showing the guns that it was proposed by the Ordnance Select Committee to strengthen, and the nature of rifled gun into which they should be converted. It has been necessary to modify the table to a certain extent, as the employment of converted guns with battering charges has since been abandoned :—

—	68-pr. 95 cwt.	10″ 84 cwt.	8″ 65 cwt.	32-prs. 63 cwt.	32-prs. 58 cwt.	32-prs. 56 cwt.	24-pr. *d.* 50 cwt.	24-pr. *d.* 48 cwt.
	a.	*a.*	*b.*	*b.*	*b.*	*b.*	*c.*	*c.*
Proposed for conversion	6·3	None made.	6·3	6·3	6·3	6·3	5·72	5·72
Weight, — cwt.	100		71	63	58	56	53	51
charge,— lbs. shot	—		—	—	—	—	—	—
charge,— lbs. shell	10		8	8	8	8	5½	5½
Projectile, — lbs.	80		64	64	64	64	56	56

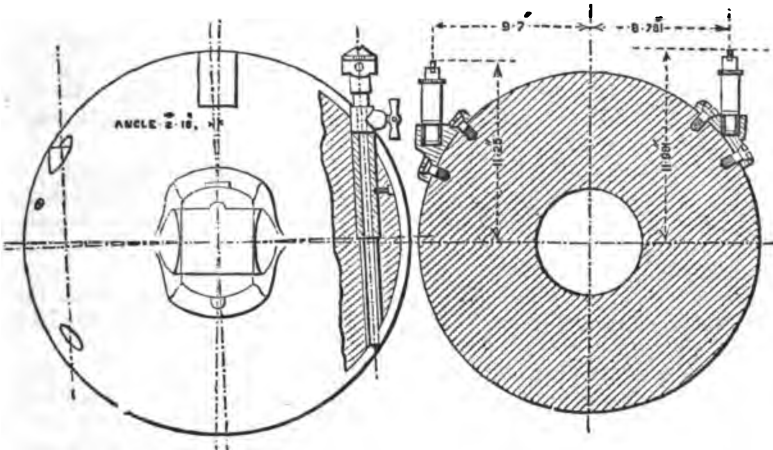
a. Powerful shell guns, and occasional use as shot guns for harbour defence.
b. Broadside guns for wooden ships, and for land-fronts of fortifications.
c. Broadside guns for small vessels, and shell guns for works of defence.
d. None of this nature have as yet been converted.

Conversion of Cast-iron S.B. Guns into R.M.L. Guns on Major Palliser's plan.

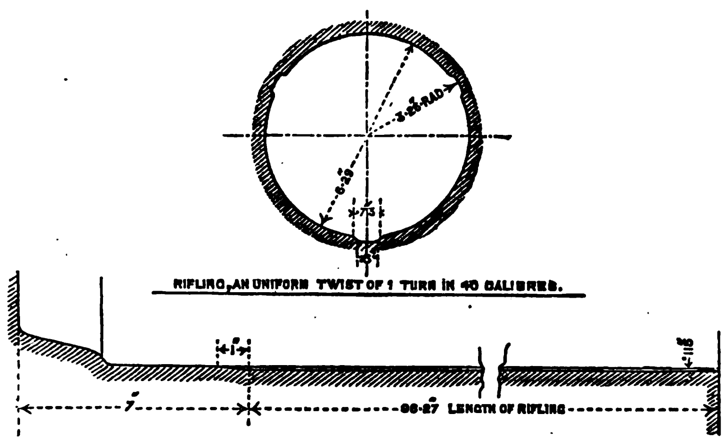
Scale $\frac{1}{32}$nd.



SIGHTING. Scale $\frac{1}{12}$th.



RIFLING. Scale $\frac{1}{8}$th.



8-inch S.B. of 65 cwt. converted into 64-pr., 71 cwt. § 1752.

The cast-iron gun is rough, second and finished bored to 10″·5 diameter, gauged, and horseshoe gauges prepared for turning the A tube. A variation of ± 0″·1 is allowed in the diameter of the bore of the cast-iron casing, but should there be any difference in the diameter at one part or another it must result in a taper from muzzle to breech. The play between the tube and the casing is not allowed to exceed 0″·007 for a length of 24″ from the breech end, and 0″·015 for the remainder of the length. **The cast-iron gun.**

The muzzle is recessed and screwed for the cast-iron collar (the use of which is to keep the tube in position), and the gas channel is bored through the breech. This is under the cascable in the first 212 guns converted at Elswick, and in all the others is to the right top of the cascable so as to be clear of the breeching rope.

The coils for the tube are made entirely of departmental bar iron specially prepared by being put three times through the roughing rolls. The tube is formed of five coils united together in the usual manner, and is rough and fine bored to 6″·238 diameter, and the recess in the breech cut and tapped for the wrought-iron cup. The cup for closing the breech end of the barrel is forged and stamped into shape under a steam hammer. It is turned inside and out and screwed on the outside with a thread of five to the inch. It is then screwed tightly home. **A tube.**

The tube in this state is proved with water pressure of 120 lbs. on the square inch to ascertain that the cup fits tightly and that there is no leakage. The breech end of the A tube is then turned over a length of 32″ for the B tube * previously bored, and a spiral gas channel 0″·05 deep and 0″·1 wide is cut round its exterior communicating with the star grooves cut in the end of the barrel, and the gas escape through the cast-iron breech.

Gas channel.

B tube.

The B tube consists of two coils united, and being rough turned to 10″·75 and finished bored to 8″, it is shrunk on with 0″·003 shrinkage in the diameter. The tube is made double at this part in order that the gas may escape through the gas channel without bursting the gun in the event of the inner layer splitting. The whole tube is then rough turned and the bore broached to 6″·29 and examined, after which the exterior is fine turned to fit the cast-iron casing with the requisite amount of play.

Putting the gun together.

The tube is now fitted into the casing, the greatest care being taken that the breech end bears fairly against the cast-iron (which is determined by means of red lead); the curved part of the end of the barrel is described with a longer radius than the corresponding curve in the cast-iron so as not to be in contact with it at that part. This space prevents the tube acting as a wedge to split open the cast-iron. When the tube is properly adjusted a cast-iron collar is securely screwed into the muzzle.

Cast-iron collar.

Wrought-iron pin.

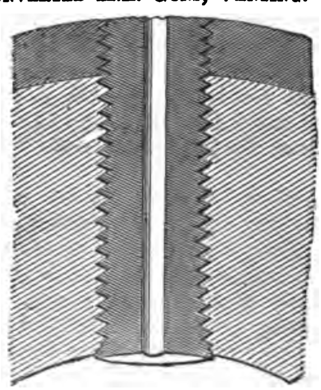
A hole 1″·25 in diameter is drilled through the cast-iron, and a short distance into the tube at 29″ from the trunnions under the chase, and, being tapped, a wrought-iron pin is screwed in to prevent the tube from shifting round.

The muzzle of the gun is cut and faced, and the bore lapped and rifled. The rifling is the same as that now used for all wrought-iron 64-prs. described at page 127.

Venting.

The vent patch is removed, as it would interfere with the lanyard when used through the guide-plate on S.S., and the old vent closed with a wrought-iron screwed plug, a new vent being drilled nearer the muzzle. This is bushed with a "through vent" (seven threads to the inch) of *hardened copper* screwed through the barrel into the breech cup, and perpendicular to the surface of the cup, *i.e.*, at an angle of 12° 25′ to the vertical. The lower thread of the screw in the gun is cut away and the end of the vent is set up into the recess thus formed.†

64-pr. Converted M.L. Guns, Venting. Scale ½.



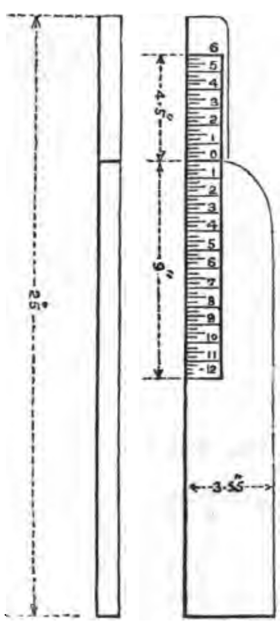
* This must not be confounded with the "B tube" of a wrought-iron gun which forms the chase, as in converted guns it goes over the breech end of the A tube.

† The first 207 guns converted at Elswick had a vent bush 1″ diameter, 12 threads to the inch, but when they require re-venting it will be with the service bush.

These guns are proved with two rounds $1\frac{1}{4}$ service charge and 64-pr. projectile, and the expansion must not exceed certain limits. No part of the bore before proof is allowed to be more than 0″·02 under the true gauge (6″·29) nor 0″·04 over that gauge after proof. They are examined with gutta percha and gauged after proof, and again tested with water pressure of 120 lbs. on the square inch to see that the breech is still perfectly tight. **Proof and examination.**

The tangent sight holes are drilled and the gun sighted, gun-metal sockets being inserted for the tangent sights. The sights are the same as the side sights for the 64-pr. wrought-iron guns, set at an angle of 2° 16″ with the vertical. There are no centre sights, and the trunnion sights are fitted in gun-metal brackets attached to the gun over the trunnions by two screws. This bracket must be removed from the gun for transport, and the holes filled with preserving screws. Wood side scales are also supplied. **Sights and sighting.**

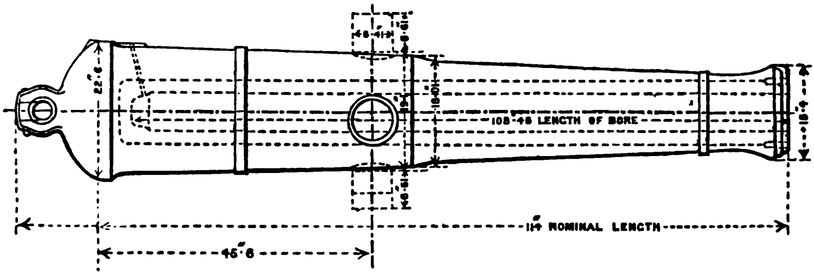
WOOD SIDE SCALE. Scale $\frac{1}{8}$th.



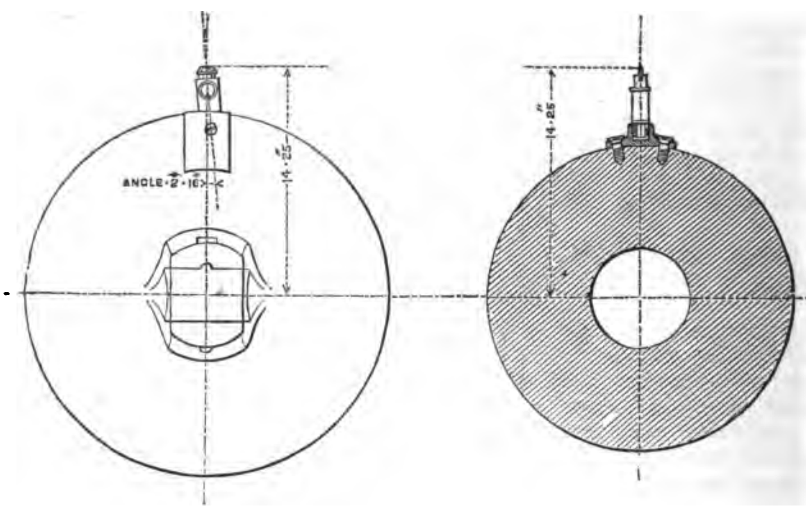
Two holes are drilled and tapped 1″·3 to the left front of the vent for the friction tube pin, and another hole is also made for the guide-plate. Axis lines are also marked on breech, muzzle, and right trunnion, and lines denoting the termination of bore and rifling.

32-pr. S.B. 58 cwt. converted into 64-pr. 58 cwt.

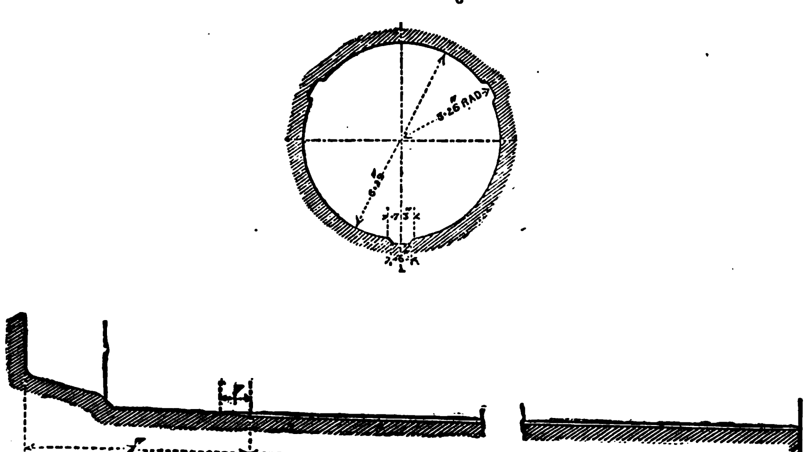
Scale $\frac{1}{32}$nd.



Sighting. Scale $\frac{1}{12}$th.



Rifling. Scale $\frac{1}{8}$th.



Conversion of 32-prs. of 58 and 56 cwt. into 64-pr. R.M.L. guns of same weight.

The method of conversion of these guns is identical with that just described. They are, however, only sighted centrally with the same centre-hind and fore sights as are supplied to the wrought-iron 64-prs. § 2066. Sighting.

The tangent sight works in a gun-metal socket let into the breech of the gun, and the drop fore sight is fitted into a gun-metal socket screwed to the gun over the trunnions.

They are vented in the original position, and those guns which had six thread bushes are re-vented with bushes of the same thread, this divergence from the pattern being stamped on the vent-field. Venting.

The vent patch is not removed, these guns being intended for L.S. only.

Conversion of 68-pr. of 95 cwt. into 80-pr. R.M.L. Guns of 5 tons.

These guns were recommended by the late Ordnance Select Committee for conversion into 7-inch R.M.L. guns, using the same projectile as the wrought-iron gun; but subsequent experiments have determined that they shall fire projectiles of 80 lbs. weight, the idea of using converted guns for "battering" purposes being abandoned. § 2220.

The conversion of these guns is identical with that already described.

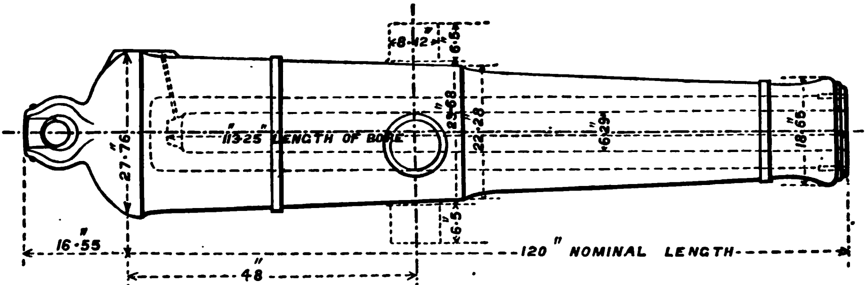
The rifling is on the "Woolwich" system, the width of the groove being 1·3″ and depth 0″·145; precisely the same groove as was used in the 80-pr. wrought-iron guns supplied to Australia some time since. Rifling.

They are side-sighted, and have drop trunnion sights fitted to the gun by gun-metal brackets similar to the 71 cwt. 64-pr. Sighting.

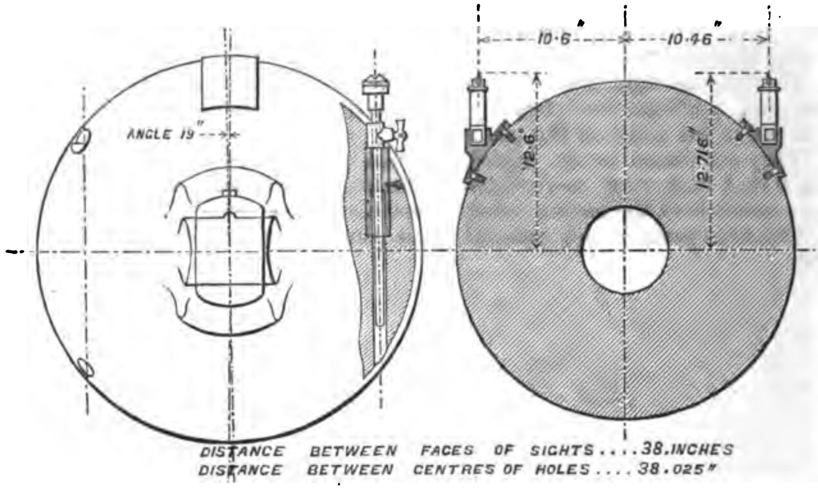
They are vented the same as the 58-cwt. gun, and guns having six thread bushes are rebushed with the same. Venting.

They are for L.S. only.

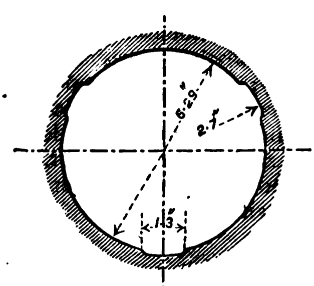
Scale $\frac{1}{32}$nd.

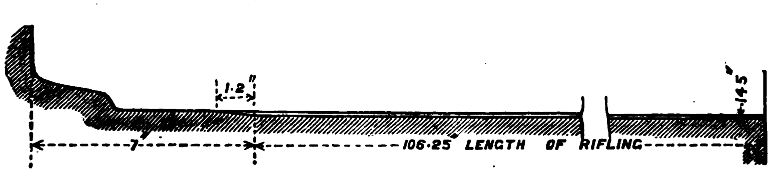


SIGHTING. Scale $\frac{1}{12}$th.



RIFLING. Scale $\frac{1}{8}$th.





Dimensions, Rifling, &c. of Muzzle-Loading Guns.

Nature, Weight, and Service.	Length.			Rifling.		Grooves.			Preponderance.
	Gun.*	Bore.	Rifling.	System.	Spiral.	Number.	Depth.	Width.	
	ft. in.	in.	in.				in.	in.	cwt.
12″ of 35 tons.—S.S., I.	15 11¾	162·5	135	Woolwich	Increasing, from 0 to 1 in 35.	9	·2	1·5	Preponderance of guns of 12 tons and upwards not to exceed 3 cwt.
13·05″ of 23 tons.—L.S. Mark I.	14 1	141·5	126	Do.	Uniform, 1 turn in 55 calibres of 13″.	10	·2	1·5	
12″ of 25 tons.—L.S. and S.S., I. & II.	14 8½	145	127	Do.	Increasing, from 1 in 100 at breech to 1 in 50 at muzzle.	9	·2	1·5	
11″ of 25 tons L.S. I. / II.	14 3 / 14 2	145	119	Do.	Increasing, from 0 to 1 in 35.	9	·2	1·5	
10″ of 18 tons L.S. and S.S. I. / II.	14 2 / 14 2¾	145·5	118	Do.	Increasing, from 1 in 100 to 1 in 40.	7	·2	1·5	
9″ of 12 tons L.S. and S.S. I.	12 3	125	107·5	Do.	Increasing, from 0 to 1 in 45 calibres.	6	·18	1·5	Nil.
9″ of 12 tons L.S. and S.S. II., III., IV., & V.†	12 3	125	104‡	Do.	Do.	6	·18	1·5	5
8″ of 9 tons S.S. I.	11 4½	118	102	Do.	Increasing, from 0 to 1 in 40 calibres.	4	·18	1·5	Nil.
8″ of 9 tons S.S. II. & III.	11 4½	118	99·5‡	Do.	Do.	4	·18	1·5	4
8″ Howitzer of 46 cwt. L.S., I.	5 1	48	35·5	Do.	Uniform, 1 turn in 16 calibres.	4	·18	1·5	2
7″ of 7 tons L.S. I.	11 10·8	126	112·5	Do.	Uniform, 1 turn in 35 calibres.	3	·18	1·5	4·5
7″ of 7 tons L.S. II. & III.	11 9½	126	110·5	Do.	Do.	3	·18	1·5	3
7″ of 6½ tons S.S. I.	10 5½	111	97·5	Do.	Do.	3	·18	1·5	5·5
7″ of 6½ tons S.S. II. & III.	10 6	111	95·5	Do.	Do.	3	·18	1·5	3
7″ of 90 cwt. S.S., I.	10 4½	111	95·5	Do.	Do.	3	·18	1·5	5
80-pr. 6·3″ of 5 tons L.S., I.	10 0	113·25	106·25	Do.	Uniform, 1 turn in 40 calibres.	3	·145	1·3	9·75
64-pr. 6·3″ of 64 cwt. S.S. I.	9 3½	98	90·5	Shunt §	Do.	3	·11 & ·08	·6 & ·4	7
64-pr. 6·3″ of 64 cwt. S.S. II.	9 5	98	90·5	Do.	Do.	3	·11 & ·08	·6 & ·4	3
64-pr. 6·3″ of 64 cwt. S.S. III.	9 3½	97·5	90·5	Do.	Do.	3	·11 & ·08	·6 & ·4	3·75
64-pr. 6·3″ of 71 cwt. L.S. and S.S.—I.	9 0	103·27	96·27	Plain groove.	Do.	3	·115	·6	6·375
64-pr. 6·3″ of 58 cwt. L.S., I.	9 6	108·45	101·45	Do.	Do.	3	·115	·6	—
40-pr. 4·75″ of 35 cwt., I. ‖	8 0	85·5	72·5	Do.	Uniform, 1 turn in 35 calibres.	3	·1	·8	lbs. 28
25-pr. 4″ of 22 cwt., I. ‖	6 7½	78	58·64	Do.	Do.	3	·1	·8	6
16-pr. 3·6″ of 12 cwt., I.	6 2·45	68·4	58·04	Modified French.	Uniform, 1 turn in 30 calibres.	3	·11	·8	10
9-pr. 3″ Wrought-iron of 8 cwt. L.S. I.	5 8½	63·5	59·8	Do.	Do.	3	·11	·8	7
9-pr. 3″ Wrought-iron of 6 cwt. S.S. I.	4 10	53	49·3	Do.	Do.	3	·11	·8	3
9-pr. 3″ Bronze, of 8 cwt. L.S. I.	5 7	63·5	59·8	Do.	Do.	3	·11	·8	8
7-pr. 3″ of 150 lb. steel (mountain).¶—I., II., & III.	2 2½	24	22	French	Uniform, 1 turn in 20 calibres.	3	·1	·6	3 lbs. III. 5 lbs. I. II.
7-pr. 3″ of 200 lb. bronze (boat).**—II.	3 0	32·15	29·15	Do.	Do.	3	·1	·6	45
7-pr. 3″ of 224 lb. bronze, Mark III.	3 0	34	32	Do.	Do.	3	·1	·6	5

* The length of a Rifled M.L. gun is measured from the face of the muzzle to the smallest diameter of the cascable excepting those having base rings, from behind which to the muzzle constitutes their nominal length.
† Mark V. differs from IV. only in preponderance, the trunnions being placed ¾″ further to the rear.
‡ Those made before 1st January 1868 have length of rifling same as Mark I.
§ Those hereafter retubed or manufactured will have same rifling as the 64-pr. converted gun.
‖ At present only experimental.
¶ These differ in the method of sighting, and the size and shape of cascable.
** Mark I. was 24 lbs. heavier and 2″ longer in bore. A few (seven) were issued to India.
Note.—For charges, &c. see table, page 195.

CHAPTER XI.

RIFLED M.L. GUNS (STEEL, WROUGHT-IRON, AND BRONZE) IN THE SERVICE.

Table of Dimensions, Rifling, &c.—7-pr.—1st., *Bronze;* 2nd., *Steel.*—9-pr. *Wrought-iron,* 8 and 6 cwt.—9-*pr., Bronze.*—16-*pr.,* 12 cwt.—25-*pr.,* 22 cwt.—40-*pr.,* 35 cwt.—64-*pr.,* Marks I., II., and III. —7-*inch,* Marks I., II., and III.—7-inch, 90 cwt., Mark I.—8-*inch,* Marks I., II., and III.—8-inch Howitzer, Mark I.—9-*inch,* Marks I. to V.—10-*inch,* Marks I. and II.—11-*inch,* Marks I. and II.—12-*inch,* 25 tons, Marks I. and II.—13-*inch,* Mark I.—12-*inch,* 35 tons, Mark I.

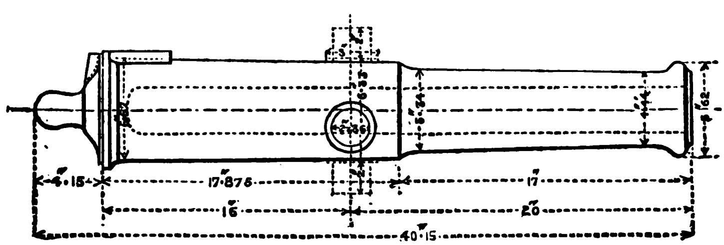
[*For Table of Dimensions, see page* 147.]

7-PR. RIFLED M.L. GUNS FOR MOUNTAIN AND BOAT SERVICE.

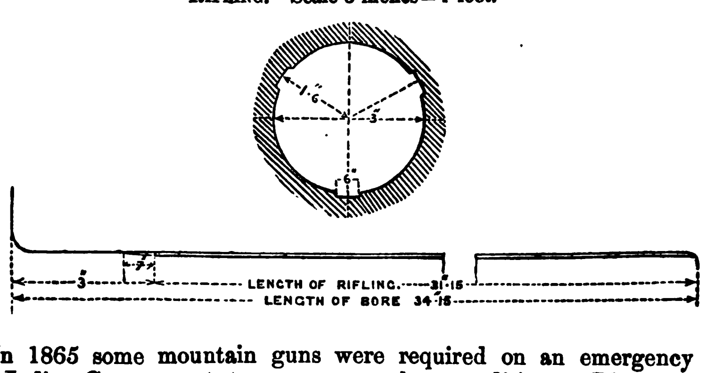
There are five patterns of this gun in the service, two of bronze, and three of steel, but the number of any one pattern made is very small.

**7-pr. Bronze. Mark I. Weight, 224 lbs.
Calibre, 3″.**

Scale 1 inch = 1 foot.



RIFLING. Scale 3 inches = 1 foot.



§ 1146. In 1865 some mountain guns were required on an emergency by the Indian Government to accompany the expedition to Bhootan, and 10 steel guns were demanded by the late Ordnance Select Committee, five of 190 lbs. weight, and five of 150 lbs. As these guns could not,

however, be supplied in time for Bhootan, six bronze 3-pr., S.B. guns of 2¼ cwt. were turned down to a weight of 224 lbs., bored to 3″, and rifled on the French system with a twist of one turn in 20 calibres, this rifling having been adopted after a long series of experiments in competition with the Shunt and Lancaster (oval) systems.

O.S.C. Proceedings, 1865, p. 212.

O.S.C. Proceedings, pp. 303, 304.

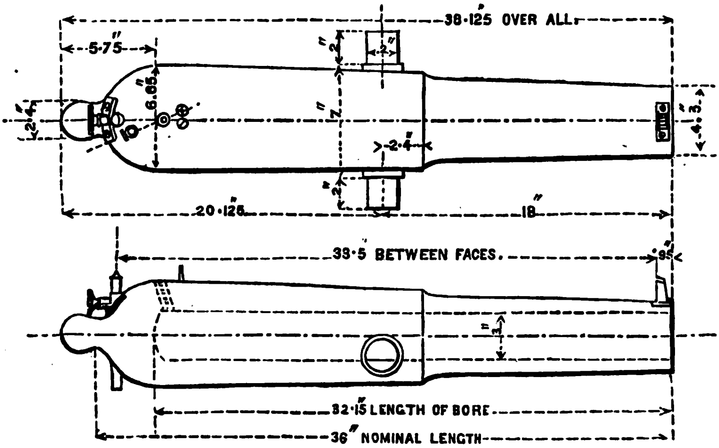
This gun was found to be too heavy for the mules in India, and a gun of 200 lbs. weight was asked for.

O.S.C. Proceedings, 1866, p. 233.

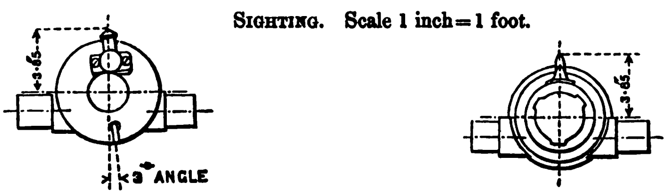
In order therefore to utilize the existing stock of bronze 3-prs., a gun was reduced to the required weight and adopted in 1866 as Mark II.

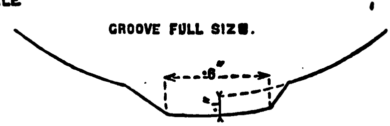
7-pr. Bronze. Mark II. Weight, 200 lbs.

Scale 1 inch = 1 foot.



SIGHTING. Scale 1 inch = 1 foot.





This differs from Mark I. gun in having the exterior turned perfectly plain, and being 2″ shorter in the bore. The swell of the muzzle is removed and a dispart sight screwed on the gun.

§ 1935. O.S.C. Proceedings, 1866, p. 107.

A pattern of this gun was sent to India in 1866 to govern manufacture, and in 1867 twelve were sent to Ireland during the Fenian disturbances. In 1870 six were sent to Canada for the Red River Expedition, and being also approved of for boat service, it was then definitely adopted into the service.

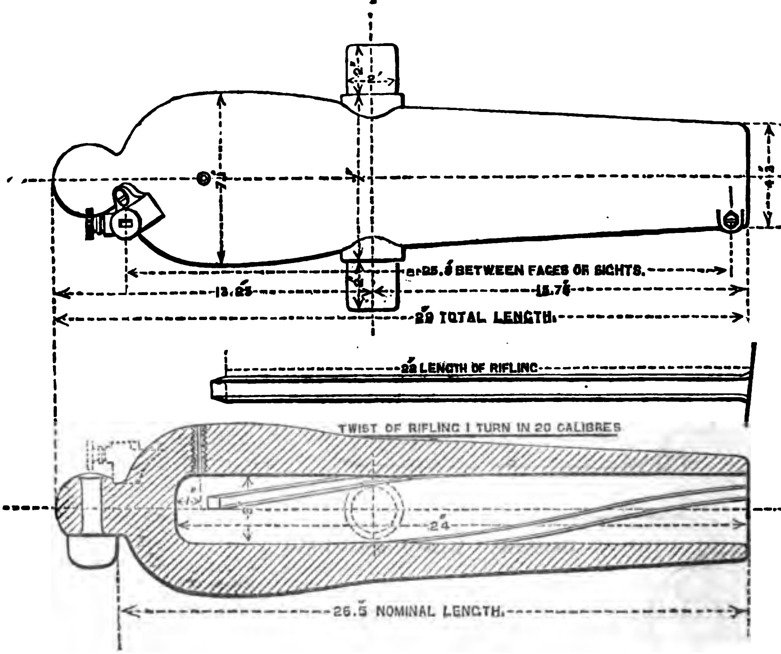
The form and preponderance of this gun (being only a conversion) are not satisfactory, and experiments have been carried out with a view to the adoption of a new bronze gun of better construction, but intended to fire the same ammunition with a heavier charge. The gun recommended is shown at Plate I., and when sealed will become, **Mark III., bronze 7-pr.**

7-pr., Steel. Mark I. 190 lbs.

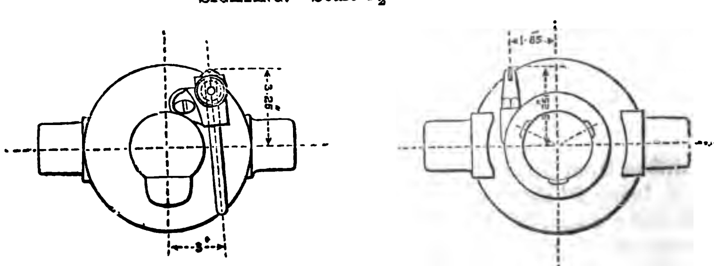
This was the first steel gun adopted, and five were made in 1865 and sent to Bhootan. This pattern is obsolete, and no more are made, but those already issued are retained in the service in India.

7-pr., Steel. Mark II. 150 lbs.

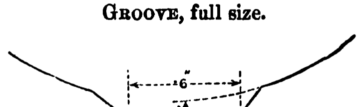
Scale $1\frac{1}{3}$ inch = 1 foot.



Sighting. Scale $1\frac{1}{2}$ inch = 1 foot.



Groove, full size.

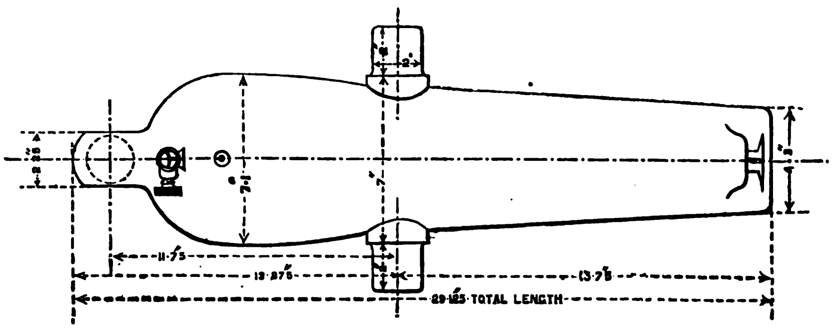


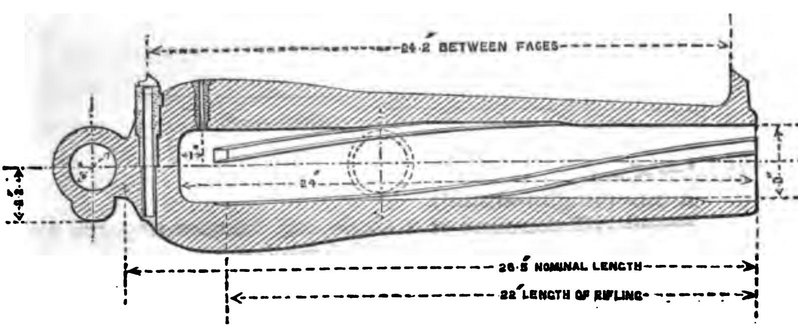
§ 1506. This is the piece commonly known as the Abyssinian gun, twelve having been sent with that expedition. They were sighted on the right side only, the tangent sight working in a gun-metal socket screwed to the breech, and the dispart sight screwed into the side of the muzzle.

The cascable had a projection underneath, which fitted into a slot in the elevating screw. A pattern of this gun was never sealed, and the gun was altered on the experience gained in Abyssinia into the present pattern.

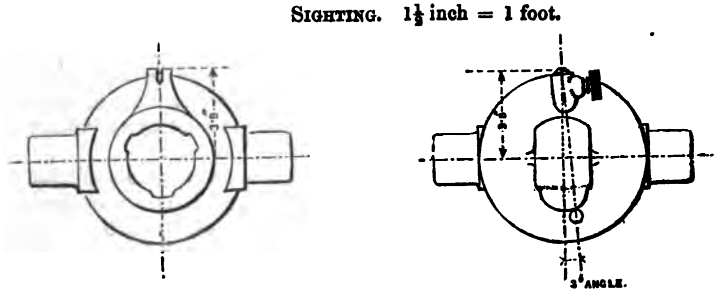
7-pr., Steel. Mark III. 150 lbs.

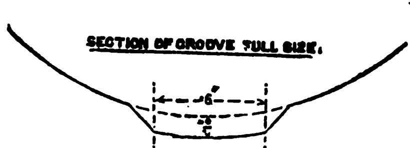
Scale $1\frac{1}{2}$ inch = 1 foot. (See Plate I.)





SIGHTING. $1\frac{1}{2}$ inch = 1 foot.





This gun differs from Mark II. in being centre sighted (see page 148, as the side sights were found to be liable to injury), and also in having a horizontal hole bored through the cascable, through which a rod can be § 1717.

passed, so as to facilitate loading or unloading, and also to enable the gun to be readily carried by men over country impassible for animals.

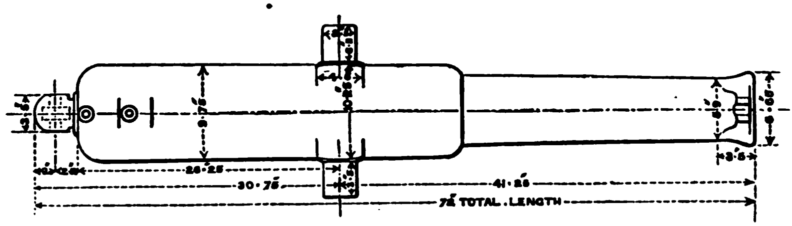
The rifling of the whole of these guns (both bronze and steel) is identical, and they fire the same ammunition.

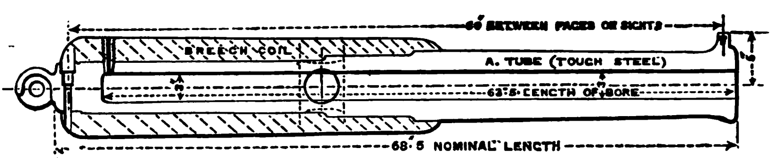
9-pr. Rifled M.L. [wrought-iron] Gun of { 8 cwt. Mark I. L.S. and S.S. / 6 cwt. Mark I. S.S.

Calibre, 3″.

9-pr., 8 cwt. Mark I.

Scale ⅛ inch = 1 foot. (See Plate I.)





§ 2067. Consists of :—

A tube (toughened steel).

Breech coil, composed of a single coil, trunnion-ring, and a coil in front of the trunnions welded together.

O.S.C. Proceedings, 1866, p. 201. O.S.C. Proceedings, 1868, p. 384. O.S.C. Proceedings, 1866, p. 328; 1867, p. 71.

In 1866 the late Ordnance Select Committee suggested the adoption of rifled M.L. guns of a pattern equally suitable for field or boat service. The gun suggested for the Horse Artillery was a 9-pr. of 6 cwt., and that for field batteries a 12-pr. 8 cwt., both having a calibre of 3″.

In 1866–7, 50 of the former and 48 of the latter were asked for by the navy, but it was decided, 21/1/67, "that for the present no alteration was to be made in the construction of rifled field guns for land service." Subsequently 20 12-prs. and 45 9-prs. were manufactured for the navy up to the point of rifling only, the system of rifling to be adopted being undecided.

In July 1870, on the approval of the recommendations of the Committee on Field Equipment for India (see page 10), it was decided to complete the whole of these guns as 9-prs. of 8 cwt. and 6 cwt., and to rifle them with the modified French grooving, so as to fire the same ammunition as the bronze gun adopted for India.

The 8 cwt. gun is now used by the Horse Artillery, light field batteries, and navy, and 120 have been manufactured for home service, in addition to those sent to India since the manufacture of bronze guns has been suspended.

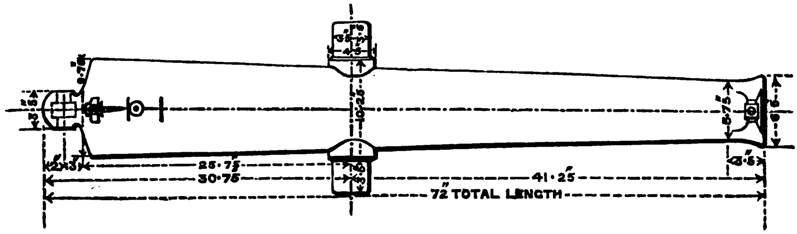
The 6 cwt. gun is used by the navy only, and some of this pattern have been ordered for the Indian naval service.

Its construction is identical with that of the 8 cwt. gun.

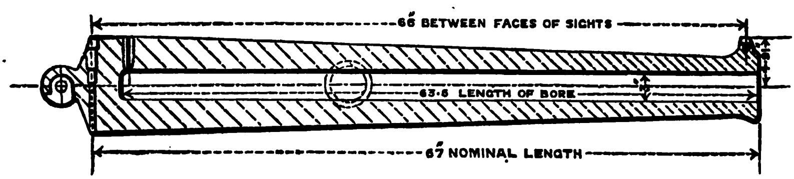
9-pr. Rifled M.L. [Bronze] Gun, 8 cwt., Mark I., for Indian Service.

Scale ⅝ inch = 1 foot.

Plan.



Sectional Elevation.



This gun was introduced for service in India in 1869, on the recommendation of the Committee on Field Equipment for India, and in 1870 the issue was extended to home service. As, however, some guns used in experimental practice were found to have become unserviceable after a very few rounds, the manufacture is discontinued. (See page 30.) § 1920.

Their manufacture is very simple. The metal is the usual gun-metal (9 copper to 1 of tin), and about 10 per cent. of new gun-metal is added to the old guns used for recasting. The mould consists of loamy sand rammed into an iron jacket, in two pieces, afterwards keyed together. The interior of the mould is coated with a wash of kaolin to give a smooth surface. The dead-head is very large, and the metal required for an 8 cwt. gun is about 26 cwt.

The casting is turned, bored, and rifled in the usual manner, the exterior of the gun being perfectly plain and conical from breech to muzzle, except the swell and dispart patch.

The sighting, rifling, venting, and other details are identical with those of the iron 9-pr. guns. (See page 129.)

Central sighting was recommended by the Committee for the following reasons :—

"Side-sighting has the advantage of giving high elevation with a short tangent bar, but minute differences in elevation are not so easily given. It has the disadvantage of leaving both the breech and trunnion sights unprotected from accidental injury. Report, 1869, p. xiii.

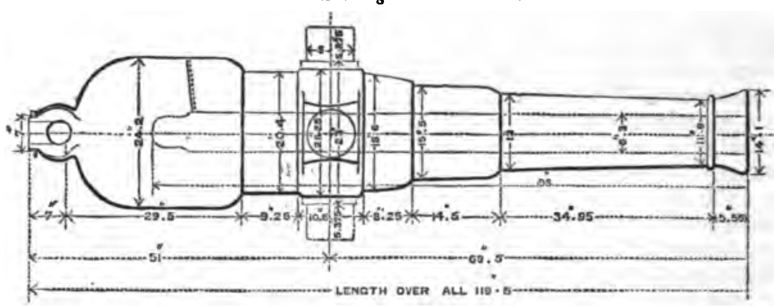
"In central sighting both sights are safe from injury. The length of radius between breech and muzzle increases the length of the degrees on the tangent scale ; this admits of a fine division of the scale, which provides for minute differences of elevation ; but, on the other hand, the tangent scale of a length equal to the diameter of the base ring will only admit of giving elevations up to 6°, equivalent to a range of about 2,500 yards. This range would suffice for ordinary purposes, but as it may be desirable to fire at higher angles, a second tangent scale reading up to 12° for a range of about 4,000 yards, has been provided."

64-pr. Rifled M.L. Guns of 64 cwt. L.S. and S.S. Calibre 6″·3.

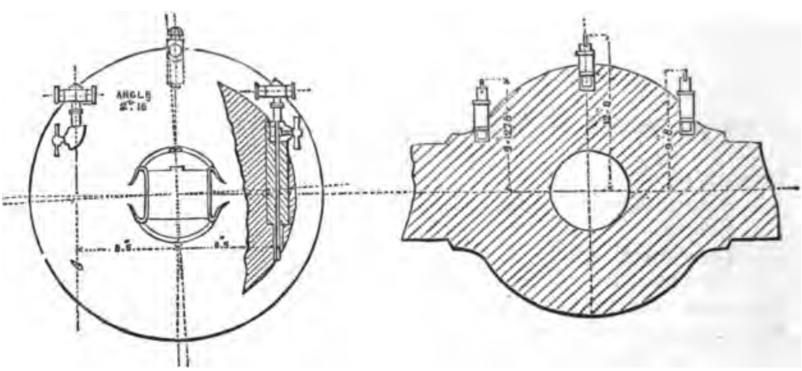
There are three patterns of this gun. (See Plate II.)

64-pr., 64 cwt. Mark I.

Scale ⅜ inch = 1 foot.



SIGHTING. Scale ⅜ inch = 1 foot.



§ 1032. MARK I. consists of :—

A tube (coiled iron).
Breech-piece and B tube.
Trunnion-ring.
4 coils.
Cascable.

The construction and external appearance of these guns is identical with that of the 64-pr. wedge, for which they were originally intended.
O.S.C. Proceedings, 1864, pp. 98, 255. They were adopted in 1864 for the navy as a broadside or pivot gun to replace the 64-pr. wedge gun, to which they objected, as it would necessitate a store of special ammunition being kept at all out stations. The calibre of 6″·3 was chosen to permit of firing 32-pr. smooth-bore spherical projectiles in cases of emergency.

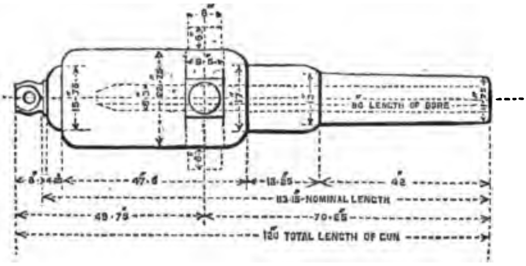
O.S.C. Proceedings, 1866, p. 246. In 1866 it was recommended and approved that this nature should replace the 7″ B.L. guns in the navy, in cases in which the latter were found too heavy.

§ 1113. O.S.C. Proceedings, 1865, p. 217. These guns are used solely as shell guns, not being sufficiently powerful against iron-clad ships; they form part of our siege equipment.

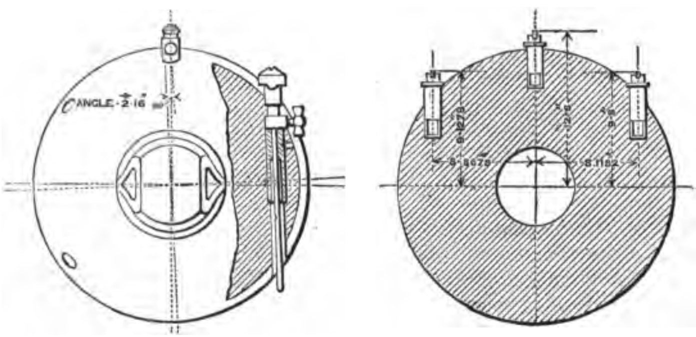
The end of the bore is closed by a copper cup, backed up by the cascable.

64-pr., 64 cwt. Mark II.

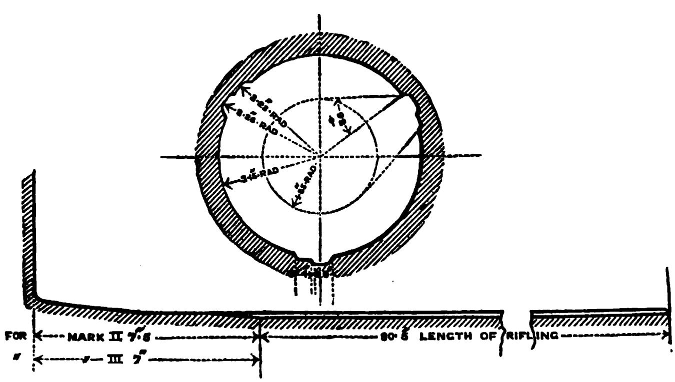
Scale ¼ inch = 1 foot.



SIGHTING. Scale ¾ inch = 1 foot.



RIFLING. Scale 2 inches = 1 foot.



MARK II. consists of :— § 1608.

A tube (coiled iron), double at the chase.
Breech-piece.
Breech coil, composed of a double coil and trunnion-ring welded together.
Coil in front of the trunnions.
Cascable.

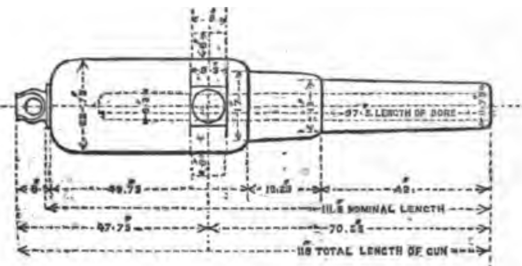
Fifty guns of this nature were recommended for manufacture in 1866, being less expensive than Mark I., and equally efficient. The end of the bore is closed by a wrought-iron plug, a copper disc intervening between it and the cascable. O.S.C. Proceedings, 1866, p. 237.

These guns differ entirely in exterior appearance from Mark I., the swell at the muzzle is dispensed with, and the gun is cylindrical from the breech to a little in front of the trunnion, the curve of the breech is also broken so as to form a step.

§ 1608. They are marked B on the left trunnion, that being the designation of this pattern when introduced into the service.

64-pr., 64 cwt. Mark III.

Scale ¼ inch = 1 foot.



§ 1608. Mark III. consists of :—

A tube, coiled iron (double at the chase).

Breech coil, composed of a triple coil, trunnion-ring, and a single coil welded together.

Cascable.

O.S.C. Proceedings, 1867, p. 11. The manufacture of this pattern was approved in 1867, experiments having proved that this construction is stronger than that in which the solid forged breech-piece is used.

O.S.C. Proceedings, 1866, p. 352. Its external appearance is the same as Mark II., excepting that the breech is rounded off.

§ 1608. Guns of this pattern issued prior to March 1868, have D stamped on the left trunnion ; that being its designation when introduced.

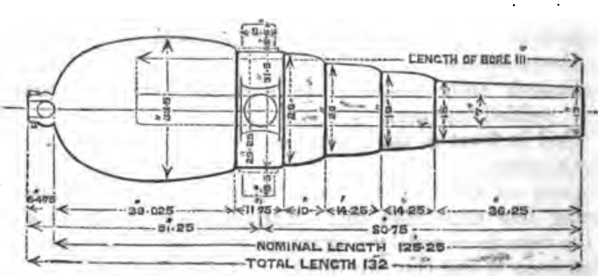
Those made since April 1871 have solid-ended steel tubes, and a B tube shrunk over the chase.

7-inch Rifled M.L. Guns of 6½ tons, S.S. only.

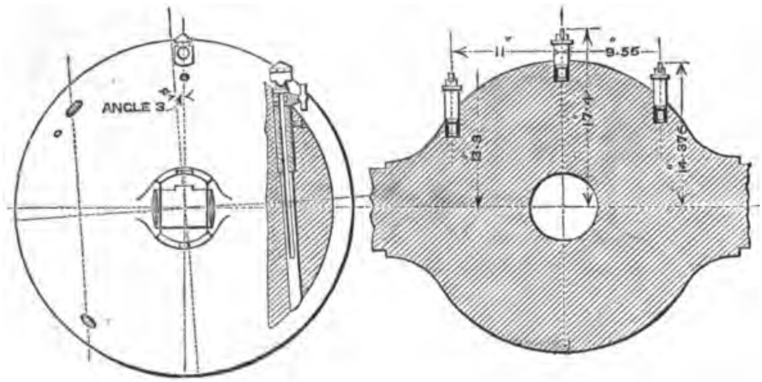
There are three patterns of this gun. (See Plate IV.)

7-inch 6½ tons. Mark I.

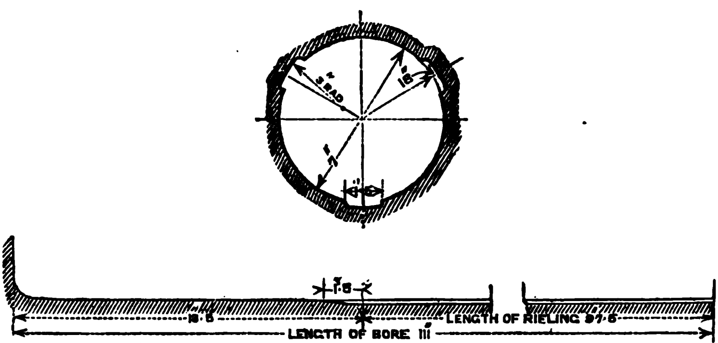
Scale ¼ inch = 1 foot.



SIGHTING. Scale ⅝ inch = 1 foot.



RIFLING. Scale 1½ inch = 1 foot.



MARK I. consists of :— § 1231.

A tube (toughened steel).
Breech-piece and B tube.
Trunnion-ring.
Six coils.
Cascable.

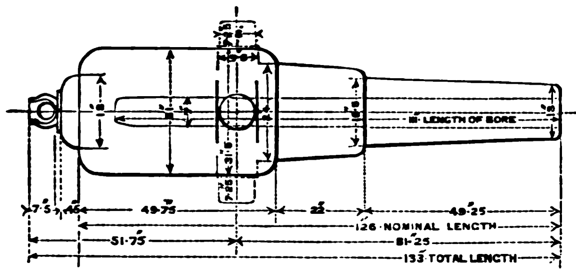
It is built on the original construction, the coils being separate and hooked. It was adopted in 1865 as a broadside or pivot gun for frigates, to replace the 7-inch B.L. and 68-pr. S.B. guns, and is now very extensively used, 331 having been made. O.S.C. Proceedings, 1865, pp. 227, 317.

Externally the breech is rounded off, giving the gun somewhat the shape of a soda water bottle, and it has several steps in front of the trunnions.

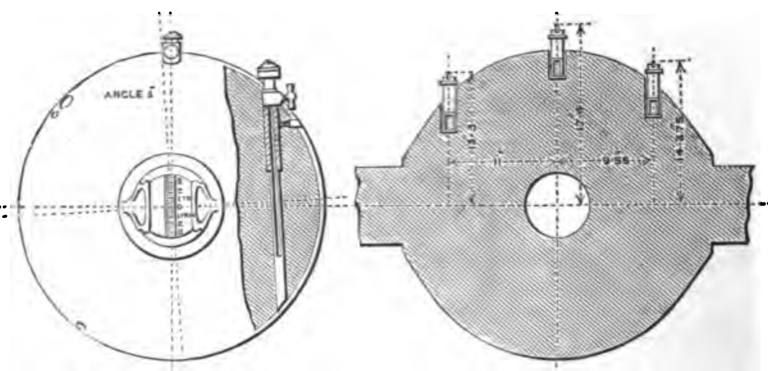
These guns are in total length 18 inches shorter than the land service 7-inch gun, being a length more suited to the requirements of the navy.

7-inch 6½ tons. Mark II.

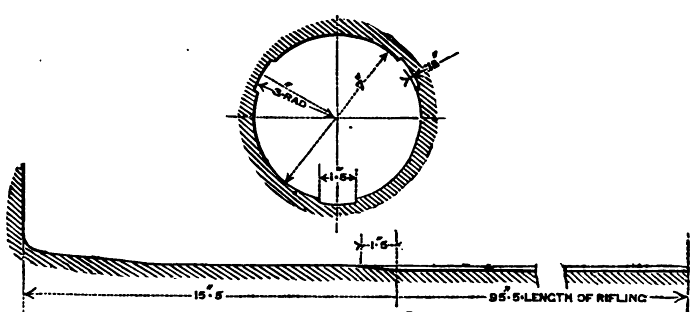
Scale ¼ inch = 1 foot.



SIGHTING. Scale ⅝ inch = 1 foot.



RIFLING. Scale 1½ inch = 1 foot.



§ 1644. MARK II. consists of :—

A tube (coiled iron).
Breech-piece.
B tube (the coil in front of the trunnions, and chase).
Breech coil :—a double coil and trunnion-ring welded together.
Cascable.

§§ 1462, 1596, 1644. Very few of this pattern were manufactured (about 20). They were introduced in 1866 and then designated and marked on the left trunnion

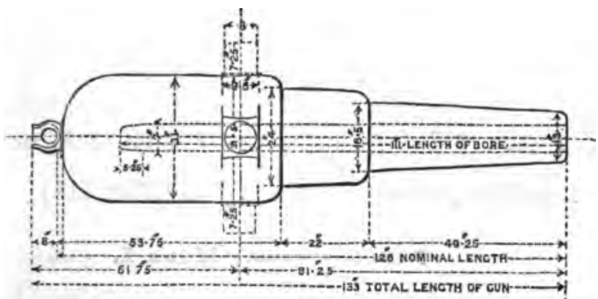
F. I. (Fraser construction); guns of this pattern issued prior to 31st March 1868, are thus known.

They had coiled iron barrels closed by an iron plug, as steel was not then finally adopted as the material for inner barrels. Any of them, however, which have since been retubed have solid ended steel barrels.

Their external appearance is similar to that of Mark II., 64-pr.

7-inch 6½ tons. Mark III.

Scale ½ inch = 1 foot.



Mark III. consists of :— § 1644.

A tube (toughened steel).

B tube (chase).

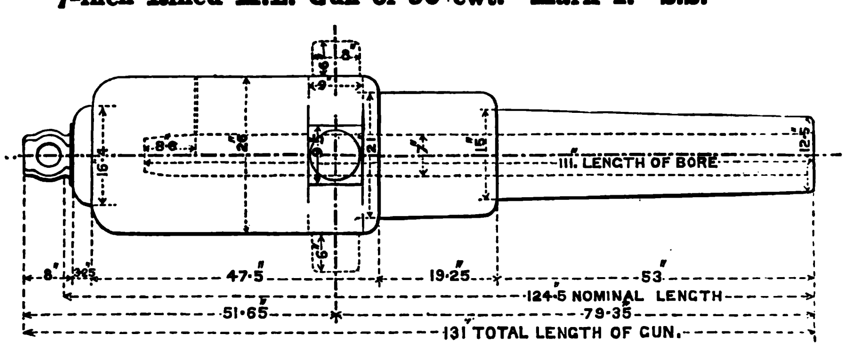
Breech coil :—a triple coil, trunnion-ring and coil in front of the trunnions welded together.

Cascable.

This construction adopted in 1866 superceded Mark II., the solid forged breech-piece being abandoned and the metal over the breech being put on in one thickness. Those issued prior to March 1868 have F II. stamped on the left trunnion. § 1462–1596.

Its external appearance is similar to Mark III., 64-pr.

7-inch Rifled M.L. Gun of 90 cwt. Mark I. S.S.



Consists of :—

A tube (toughened steel).

B tube (chase).

Coiled breech-piece.

Breech coil :—A single coil and trunnion ring welded together.

Cascable.

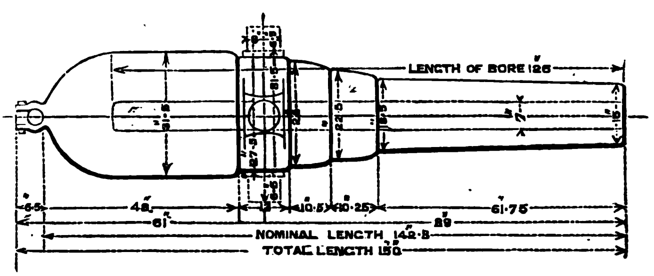
At the request of the Admiralty some 7-inch $6\frac{1}{2}$ ton guns under manufacture have been completed as 90 cwt. guns for the armament of wooden vessels. The bore of the piece has been left untouched, but the exterior has been turned down all over, and slightly shortened. In order to rectify the preponderance and the position of the trunnions, a large part of the jacket has been turned off and an extra layer of iron shrunk over the breech. The construction of this gun is therefore similar to that of 9-inch gun Mark V. (see Plate VI.).

7-inch Rifled M.L. Gun of 7 tons, L.S. only.

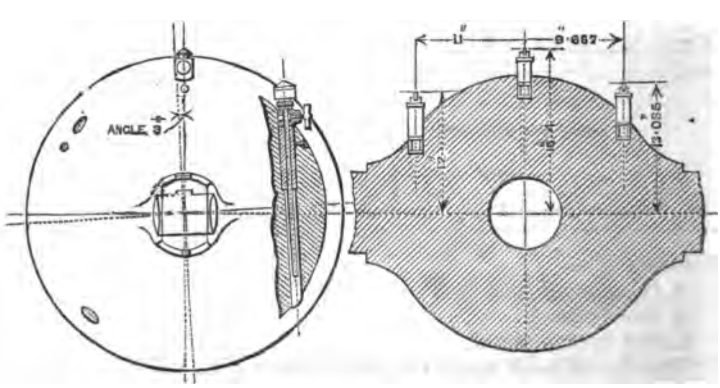
There are three patterns of this gun. (See Plate III.)

7-inch 7 tons. Mark I.

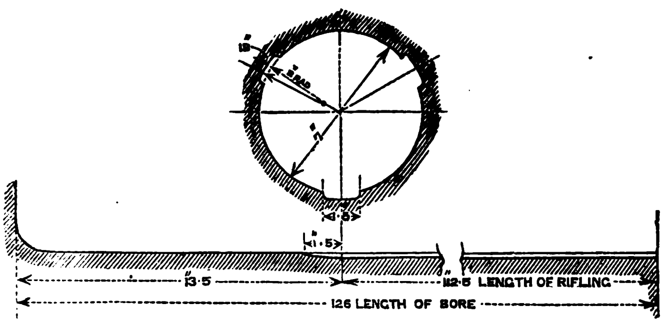
Scale $\frac{1}{4}$ inch = 1 foot.



SIGHTING. Scale $\frac{3}{8}$ inch = 1 foot.



RIFLING. Scale 1½ inch = 1 foot.



MARK I. consists of :— § 1230.

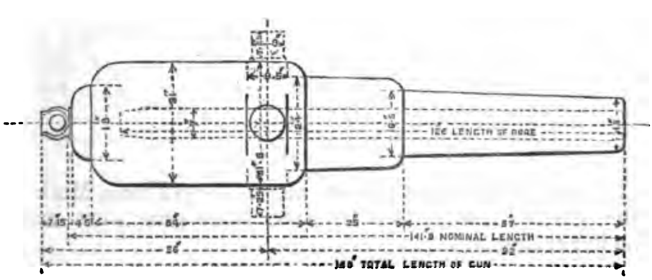
A tube (toughened steel).
Breech-piece and B tube.
Trunnion-ring.
Five coils.
Cascable.

This nature is entirely a land service gun, and was introduced in 1865 as a battering gun for coast defence. It is built on the original construction, and externally is similar to the 7-inch 6½ ton gun, Mark I. The B tube of this pattern is covered by an additional thin coil so as to reduce the preponderance, which was found to be excessive. 51 were manufactured.

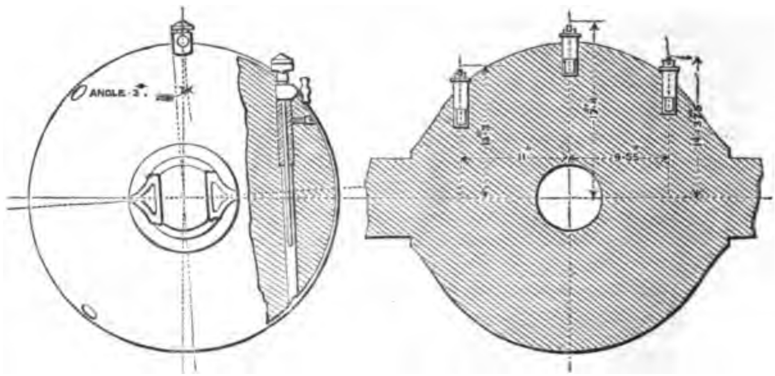
O.S.C. Proceedings, 1865, p. 316.
O.S.C. Proceedings, 1866, p. 119.

7-inch 7 tons. Mark II.

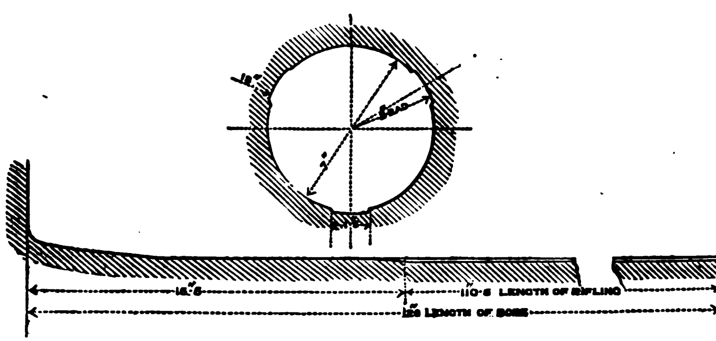
Scale ¼ inch = 1 foot.



Sighting. Scale $\frac{5}{8}$ inch = 1 foot.



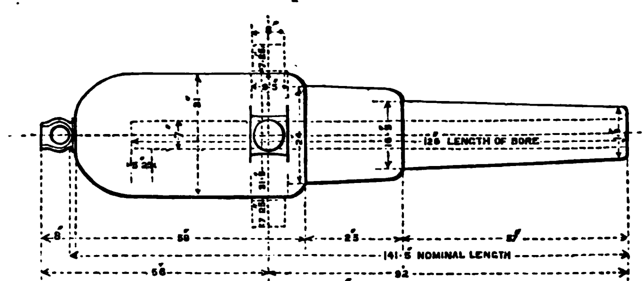
Rifling. Scale $1\frac{1}{2}$ inch = 1 foot.



§ 1607. Mark II., introduced in 1866, consists of same parts as Mark II., 7-inch $6\frac{1}{2}$ ton gun, and differs from it only in length. There were only two made, and they are marked F. I. on the left trunnion.

7-inch 7 tons. Mark III.

Scale $\frac{1}{4}$ inch = 1 foot.



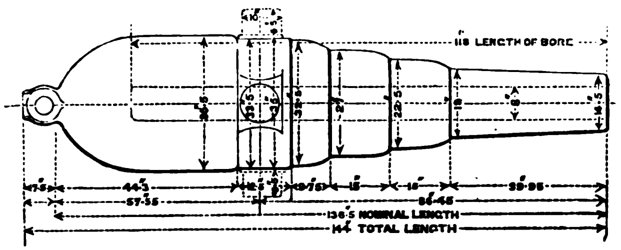
§ 1607. Mark III., introduced in 1866, differs only in length from Mark III., 7-inch $6\frac{1}{2}$ ton gun. Previous to April 1868 these guns were marked F. II. on the left trunnion.

8-inch Rifled M.L. Gun of 9 tons, S.S.

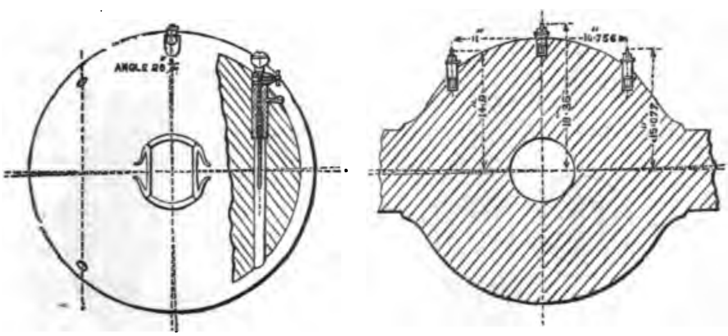
There are three patterns of this gun. (See Plate V.)

8-inch 9 tons. Mark I.

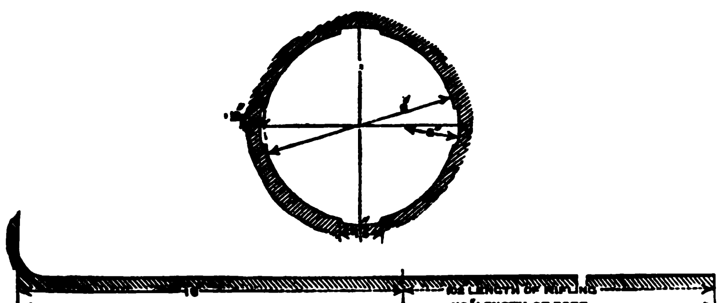
Scale $\frac{1}{4}$ inch = 1 foot.



SIGHTING. Scale $\frac{1}{2}$ inch = 1 foot.



RIFLING. Scale $1\frac{1}{2}$ inch = 1 foot.



MARK I. consists of:— § 1289.

- A tube (toughened steel).
- Breech-piece and B tube.
- Trunnion-ring.
- Five coils.
- Cascable.

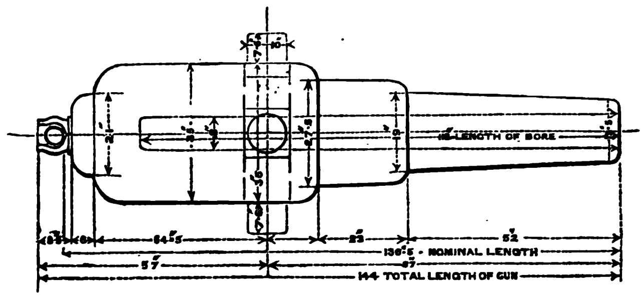
These guns were introduced in 1866 for S.S., and a few have since been made for L.S. They are used by vessels not sufficiently heavy to carry 9-inch guns. O.S.C. Proceedings, 1866, p. 251.

Its exterior is similar to Mark I. 7-inch $6\frac{1}{2}$ ton gun.

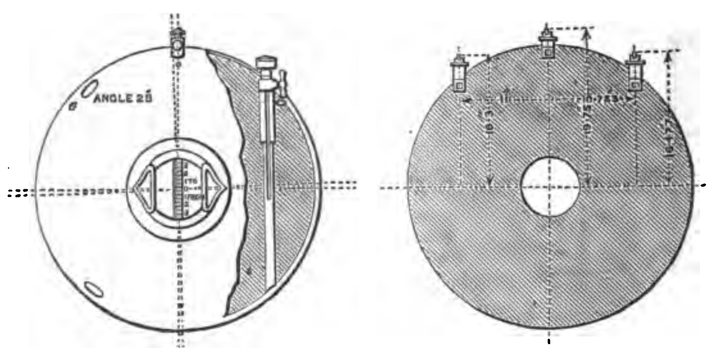
The number made of this pattern is 76.

8-inch 9 tons. Mark II.

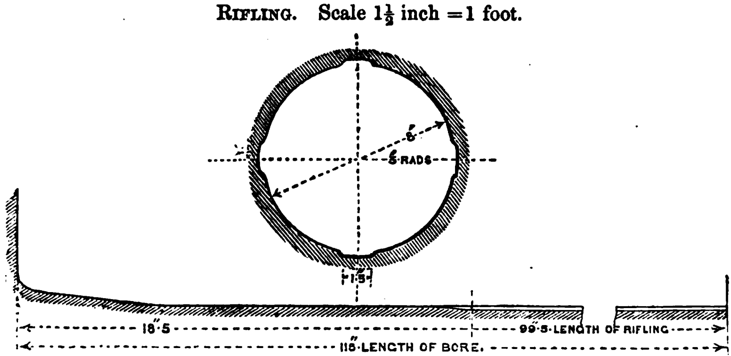
Scale ¼ inch = 1 foot.



Sighting. Scale ½ inch = 1 foot.



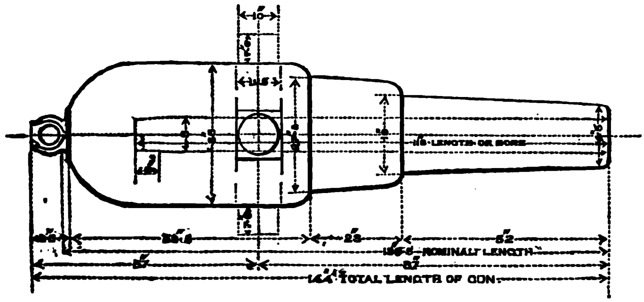
Rifling. Scale 1½ inch = 1 foot.



§ 1643. Mark II., introduced in 1866, consists of same parts as Mark II. 7-inch 6½ ton gun, and the exterior form is similar. Only six were made, and they are marked F. I.

8-inch 9 tons. Mark III.

Scale $\frac{1}{4}$ inch = 1 foot.



Mark III., introduced in 1866, consists of same parts as Mark III. §1643.
7-inch $6\frac{1}{2}$ ton guns, and the exterior form is similar. Those made previous to April 1868 were marked F. II.

8-inch Rifled M.L. Howitzer of 46 cwt., L.S. Mark I.

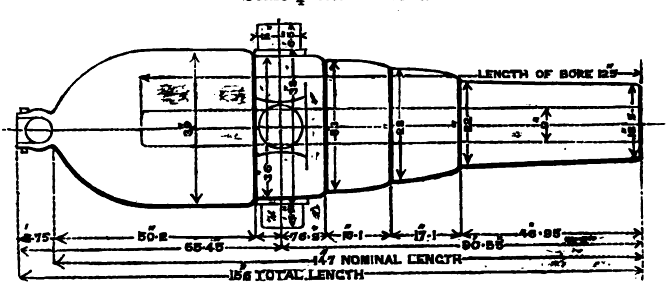
Consists of the same parts as the Mark III. 7-inch $6\frac{1}{2}$ ton gun, and its exterior form is similar, except that it is much shorter and has a button instead of a cascable loop. Thirty of these pieces are being manufactured to replace the S.B. Mortars in the siege train.

9-inch Rifled M.L. Gun of 12 tons, L.S. and S.S.

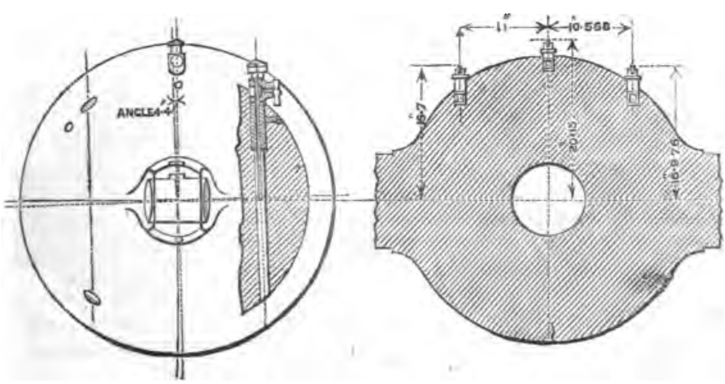
There are five patterns of this gun. (See Plate VI.)

9-inch 12 tons. Mark I.

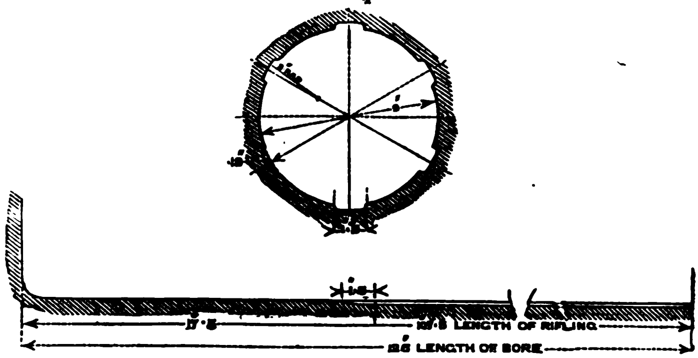
Scale $\frac{1}{4}$ inch = 1 foot.



Sighting. Scale $\frac{1}{2}$ inch = 1 foot.



Rifling. Scale 1¼ inch = 1 foot.



§ 1229. **Mark I.** consists of:—
- A tube (toughened steel).
- Breech-piece.
- B tube.
- Trunnion-ring.
- Seven coils.
- Cascable.

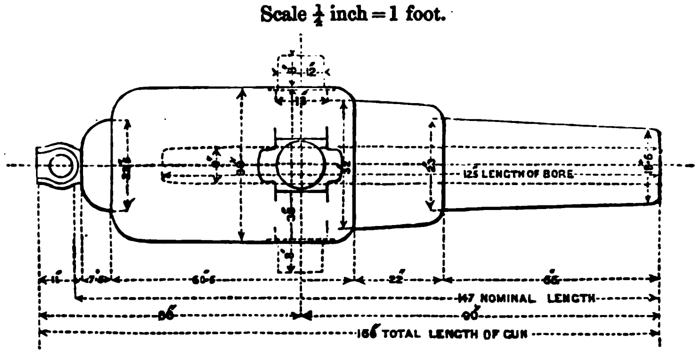
Introduced in 1865 as a broadside gun for heavy iron-clad ships, and also for the defence of harbour and sea fronts. 190 were made.

It is a very powerful gun for its weight.

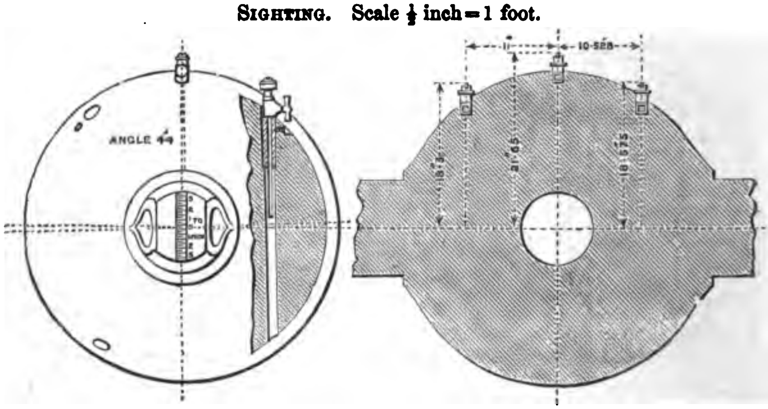
Externally it has several steps in front of the trunnions, and is rounded off at the breech.

9-inch 12 tons. Mark II.

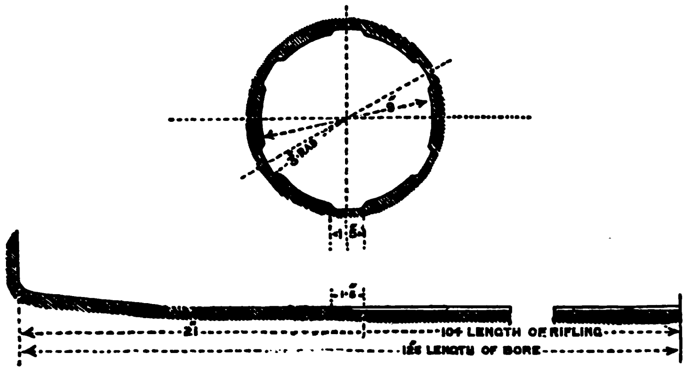
Scale ½ inch = 1 foot.



Sighting. Scale ½ inch = 1 foot.



RIFLING. Scale 1¼ inch = 1 foot.



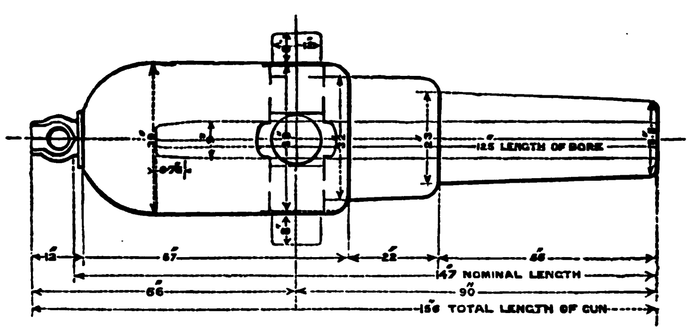
MARK II. consists of:— § 1642.

A tube (toughened steel).
Breech-piece.
B tube.
Breech coil:—Double coil, trunnion-ring, and a coil in front of the trunnions welded together.
Cascable.

Introduced in 1866, only 26 being made. They differ from Mark II. 7-inch and 8-inch in having steel barrels, but the external appearance is the same. They are marked F. I. on the left trunnion.

9-inch 12 tons. Mark III.

Scale ¼ inch = 1 foot.



MARK III. consists of:— § 1642.

A tube (toughened steel).
B tube.
Breech coil:—Triple coil, trunnion-ring, and a double coil in front of the trunnions welded together.
Cascable.

Was introduced in 1866, and is similar in construction and exterior form to Mark III. 7-inch. Those manufactured previous to April 1868 are marked F. II. 136 of this pattern were manufactured.

9-inch 12 tons. Marks IV. and V.

§ 1906. Marks IV. and V. consist of:—

§ 2219. A tube (toughened steel).

B tube.

Coiled breech-piece.

Breech coil:—double coil, trunnion-ring, and single coil in front of the trunnions welded together.

Cascable.

O.S.C. Proceedings, 1869, p. 172. This pattern was adopted in 1869, and its external appearance is the same as Mark II. Mark V. differs from IV. in preponderance only, the trunnions being placed $\frac{3}{8}''$ further to the rear.

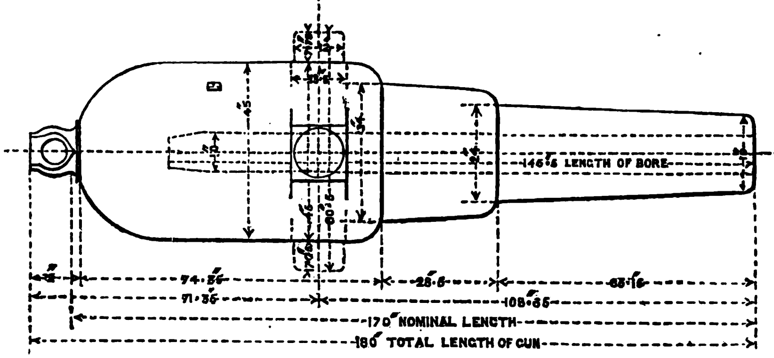
Note.—9-inch guns and upwards now manufactured have two layers over the breech, *i.e.*, a coiled breech-piece covered by a breech coil, this construction being considered preferable to the Mark III. for very heavy guns, on account of the difficulty of ensuring the soundness of the interior of a large mass of iron.

10-inch Rifled M.L. Gun of 18 tons, L.S. and S.S.

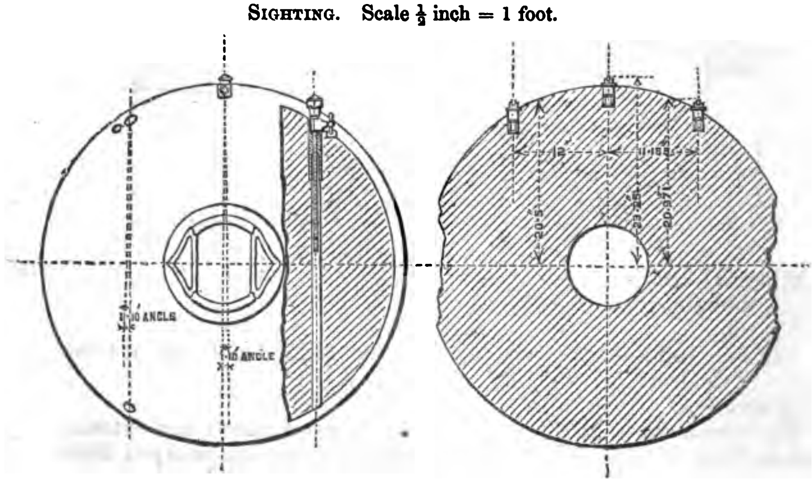
There are two patterns of this gun. (See plate VII.)

10-inch 18 tons. Mark I.

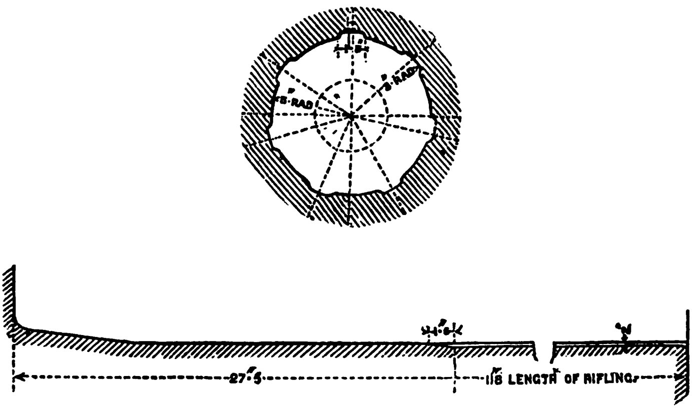
Scale $\frac{1}{4}$ inch = 1 foot.



Sighting. Scale $\frac{1}{2}$ inch = 1 foot.



RIFLING. Scale 1 inch = 1 foot.



MARK I. consists of:— § 1688.

A tube (toughened steel).
B tube.
Breech coil:—triple coil, trunnion-ring, and a triple coil in front of the trunnions welded together.
Cascable.

Proposed by Commodore Heath, R.N., in 1865, owing to the success of the 9-inch gun, and introduced in 1868 for the navy as a most powerful broadside gun, H.M.S. "Hercules" being armed with it. The formidable character of these guns may be imagined, when at 2,000 yards it strikes nearly as hard a blow as the 9-inch does at the muzzle, and its power of penetration at 1,500 yards is nearly equal to the 9-inch at the muzzle. O.S.C. Proceedings, 1865, p. 390. O.S.C. Proceedings, 1868, p. 86.

It is now used by the land service for coast defence.

Its external appearance is similar to Mark III. 9-inch.

There are 18 guns of this pattern.

10-inch 18 tons. Mark II.

MARK II. consists of:— § 1905.

A tube (toughened steel).
B tube.
Triple coil in front of the trunnions. (Belt.)
Coiled breech-piece.
Breech coil:—double coil, and a trunnion-ring welded together.
Cascable.

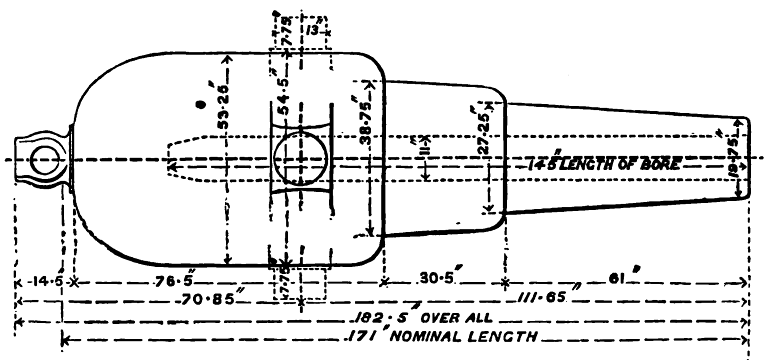
Adopted in 1869. Its exterior form is the same as Mark V. 9-inch, upon which type it is constructed. O.S.C. Proceedings, 1869, p. 122.

11-inch Rifled M.L. Gun of 25 tons, L.S.

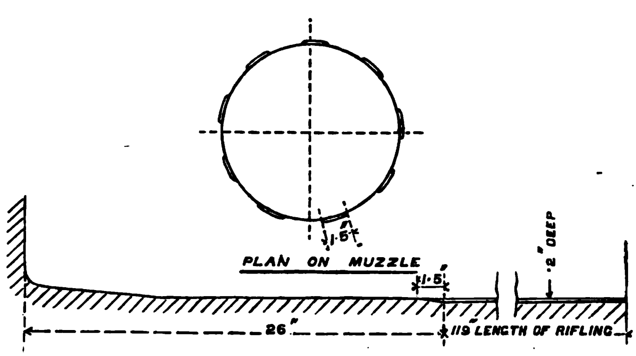
There are two patterns of this gun. (See plate VIII.)

11-inch 25 tons. Mark I.

Scale $\frac{1}{48}$.



RIFLING. Scale $\frac{1}{12}$.



§ 2102. MARK I. consists of :—

A tube (toughened steel).

B tube.

Breech coil :—triple (or quadruple) coil, trunnion-ring, and triple coil in front of the trunnions welded together.

Cascable.

Recommended in 1867 on account of the great penetration obtained with the 10-inch gun, and also to try it in comparison with the service 12-inch gun of the same weight and length of bore, in order "to determine what calibre and proportional length of bore are best adapted to "a gun of from 23 to 25 tons weight, or in other words, what calibre in "a given weight and length of gun is best adapted to the profitable "consumption of the powder charge." O.S.C. Proceedings, 1867, pp. 15, 94

In the meantime, manufacture of these guns of 25 tons weight proceeded as if for 12-inch, but they were only bored up to 11 inches and left unrifled, until the question was decided 1st October 1870, in favour of the smaller calibre.

It is for use in the navy for cupola ships, and by L.S. for coast defence.

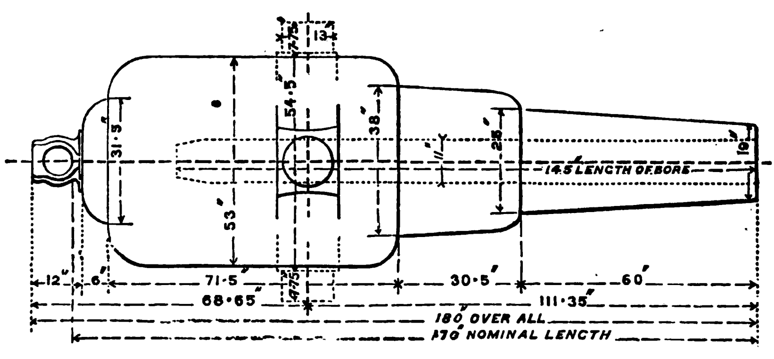
Externally it has a step in front of the trunnions, and is rounded off at the breech.

Had the calibre been 12 inches, it would have constituted Mark III. of that nature.

Only 7 of this pattern have been made.

11-inch 25 tons. Mark II.

Scale $\frac{1}{48}$.



Mark II. consists of :— § 2102.

A tube (toughened steel).

B tube.

Triple coil in front of the trunnions.

Coiled breech-piece.

Breech coil :—double coil and a trunnion-ring welded together.

Cascable.

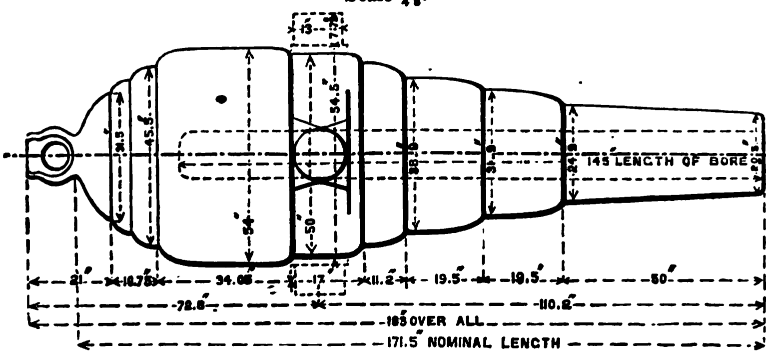
Adopted in 1871. Its external appearance is the same as Mark V., 9-inch.

12-inch Rifled M.L. Gun of 25 tons, L.S. and S.S.

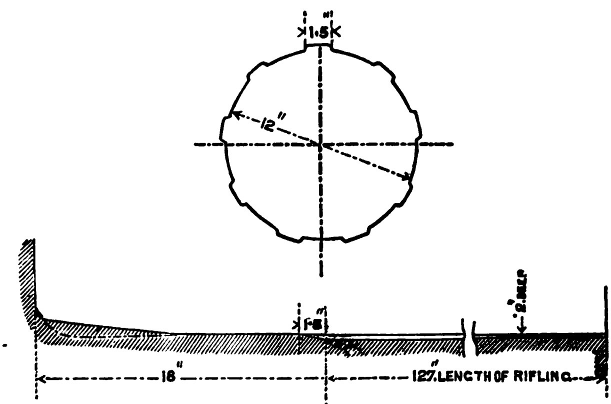
There are two patterns of this gun. (See plate IX.)

12-inch 25 tons. Mark I.

Scale $\frac{1}{48}$.



Rifling. Scale $\frac{1}{12}$.



§ 2022. Mark I. consists of:—

- A tube (toughened steel).
- Breech-piece.
- B tube.
- Trunnion-ring.
- 7 coils.
- Cascable.

O.S.C. Proceedings, 1864, p. 190.

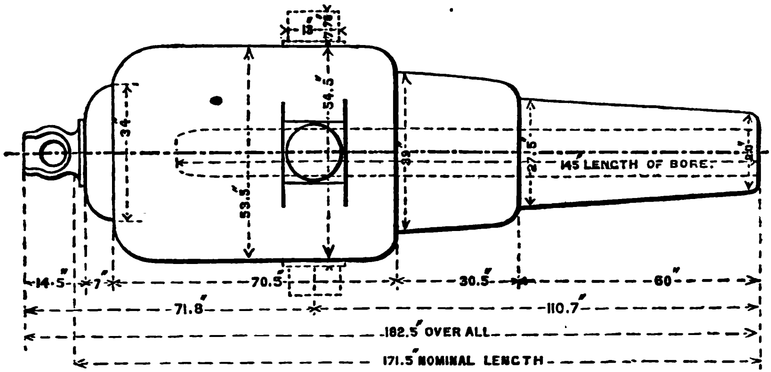
This gun was recommended in 1864 on the belief that it would give higher initial velocity than the 13-inch gun, but the trial was not carried out till 1866.

It is known externally by having steps in front of the trunnion, and also at the breech. There are only four of this construction in the service, and their weight is 23½ tons, but by an order of 3rd July 1868, "to avoid confusion and the necessity of separate series on account of "weight it is approved that they all bear the same designation, viz., "Ordnance, Rifled M.L. 12-inch of 25 tons," this being the weight of the later patterns.

They are used for turret ships and coast defence.

12-inch 25 tons. Mark II.

Scale $\frac{1}{48}$.



MARK II. consists of:— § 2022.

A tube (toughened steel).
B tube.
Triple coil in front of trunnions.
Coiled breech-piece.
Breech coil:—double coil and trunnion-ring welded together.
Cascable.

This pattern was introduced in 1866, but the first gun made in that year (No. 5) is exceptional in having a coiled iron tube and also a solid forged breech-piece. O.S.C. Proceedings, 1866, p. 256.

Externally they are known by the step at the breech. They weigh about 25 tons (see Mark I.).

The number of 12″ 25 ton guns manufactured up to June 1871 is 15. Of these four are on the original or Mark I. construction and 9 on the Mark II. pattern (including the exception noted above).

The remaining two guns, Nos. 20 and 21, are the same as the 11″ gun Mark I., but they do not form a distinct pattern, and are known by their numbers. The breech of these two guns is rounded.

The 12-inch Rifled M.L. Gun of 35 tons. Mark I. S.S.

There is only one pattern of this gun. (See plate X.)

Consists of:—

A tube (toughened steel).
B tube.
Triple coil in front of the trunnion.
Coiled breech-piece.
Breech coil:—double coil and a trunnion-ring welded together.
Cascable.

The first of these guns was completed in February 1871 as a 700-pr. of 11″·6 calibre, but experiments having proved that this calibre is not suitable for the efficient combustion of 120 lbs. of "P" (Pebble) powder, the proposed battering charge of the gun, it was decided to bore it out experimentally to 12″.

This calibre has been adopted for the whole of these guns, but it is proposed to make those for L.S. about three feet longer in the bore.

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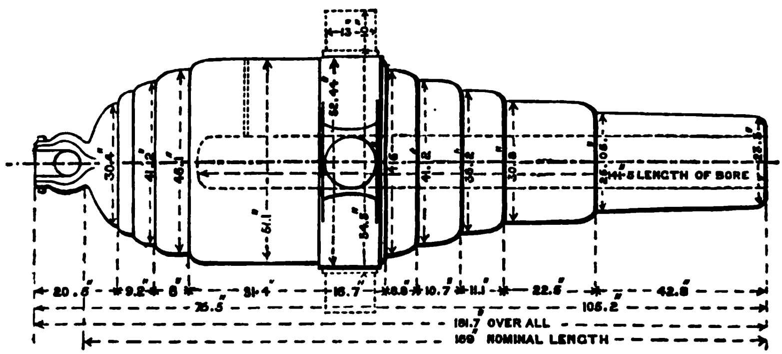
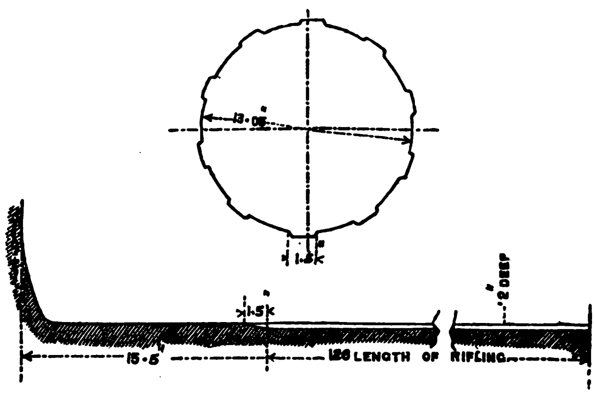
§ 2022. **13″·05 Rifled M.L. Gun of 23 tons. Mark I. L.S. only.**

There is only one pattern of this gun.

Scale $\frac{1}{48}$.



RIFLING. Scale $\frac{1}{12}$.



Consists of :—

A tube, steel (not toughened), with *loose* end.
Breech-piece.
B tube.
Trunnion-ring.
15 coils.
Cascable.

O.S.C. Proceedings, 1867, pp. 98–102.

This nature of gun was brought forward in 1862 as the 600-pr., having a calibre of 13·3 inches. In 1864 four of these guns were ordered having a calibre of 13 inches, shunt rifling, uniform spiral and A tubes of untempered steel, closed by the Elswick loose end similar to that in the 64-pr., Mark II. (see page 157). Of these four, by March 1867, two were rendered unserviceable during experimental practice at Shoeburyness by splitting their A tubes and some of the coils, and another by splitting its outer coil. The latter was repaired with a new outer coil shrunk on, and is now serviceable, and the fourth having passed proof is serviceable.

The cause of failure in the first two was attributed to the following circumstances: — *First.* The steel tubes not having been tempered. *Secondly.* The guns being rifled on the shunt system, the defect due to sharp angles in this rifling being evinced by the fractures running along the angles in both guns. *Thirdly.* The guns having been fired with projectiles heavier than they were designed to fire (up to 670 lbs.).

In the case of the third gun the splitting of its outer coil was no doubt owing to the coil having been shrunk on with too great tension. O.S.C. Proceedings, 1866, p. 259.

In the meantime the 12″ calibre had been adopted, and it was decided that the rifling of the two guns which remained should be converted to the "Woolwich" form of groove, the calibre being increased to 13·05 inches, a manufacturing necessity owing to re-rifling. O.S.C. Proceedings, 1867, p. 101.

Thus it is that these two guns have an exceptional calibre, uniform twist, and 10 grooves.

The original 600-pr. "Big Will" is now mounted at Southsea Castle, and is still serviceable, but being experimental and retaining the shunt rifling is not classed as a service gun.

The following table shows in a condensed form the various patterns of guns in use.

TABLE showing the CONSTRUCTION of the VARIOUS "MARKS" of RIFLED M.L. GUNS.

Nature.	Original Construction.	Fraser Modification with Forged Breech-piece.	Fraser Modification with One Layer.	Fraser Modification with Two Layers.	Remarks.
	Mark.	Mark.	Mark.	Mark.	
64-pr., 64 cwt. -	I.	II.‖	III.*†	—	* These are now the service patterns for future manufacture.
7-inch, 6½ or 7 tons -	I.	II.‖	III.*	—	
8 „ 9 tons -	I.	II.‖	III.*	—	
9 „ 12 „ -	I.	II.¶	III.	IV., V.*	
10 „ 18 „ -	—	—	I.	II.*	
11 „ 25 „ -	—	—	I.	II.*	
12 „ 25 „ -	I.	—	—‡	II.*	‖ Iron tubes.
13·05 inch, 23 tons -	I.§	—	—	—	¶ Steel tubes.
12-inch, 35 tons -	—	—	—	I.*	

N.B.—Guns marked F. or F.I. are of Mark II. construction.
„ „ F.II. are of Mark III. construction.
64 pr. guns „ B. are of Mark II. construction.
„ „ D. are of Mark III. construction.

† Those manufactured after April 1871 have steel tubes, former guns wrought-iron.

‡ There are two 12-inch 25-ton guns on this construction similar to Mark I. 11-inch, but they do not constitute a separate pattern, being known by their Nos. (20 and 21).

§ There are only two guns of this nature.

CHAPTER XII.*

EXAMINATION, PRESERVATION, AND REPAIRS, ON SERVICE, OF GUNS AND THEIR FITTINGS.

Importance of this subject.—Periodical examinations.—Cleaning guns.—Defects common to all materials.—Defects in *wrought-iron barrels*.—Ditto in *steel*.—*Sentence on barrels* generally, and with reference to specific defects.—*Sentence of guns in which a shell has burst*.—Examination of *vents* and rules for *sentencing*.—Examination and repair of *breech-screws* and *fittings*.—Ditto *vent-piece* and *breech bush copper*.—Refacing 7-inch vent-piece.—Renewing breech bush of 7-inch and wedge guns.—Renewing copper vent bush.—Wedge and stopper.—Exterior of guns.—Gutta percha impressions.—Method of using wood blocks.—*Preservation of guns and their fittings*.—Painting.—Browning.—Bronzing.—Blueing.—Preservation of B.L. guns in store.—Preservation of sights, elevating plates and preserving screws.—Adjusting "Moncrieff" sights.—Return of the state of rifled ordnance.—List of tools for cleaning and examination of rifled ordnance.—List of venting tools.

Importance of this subject.

The importance of this subject can scarcely be overrated. It is one on which every Artillery officer should be well informed, as he may be called upon at any time to inspect the armament of a ship or battery, and he ought at least to be able to give a trustworthy opinion regarding the safety or otherwise of the guns in his own immediate charge.

As however it requires great practice and experience in order to become a competent judge of the various conditions of all the different natures of guns in the service, it has been directed that *final* condemnation shall be pronounced only by the authorities of the Royal Gun Factories. An intelligent officer who has been taught in the Gun Factories how to inspect Ordnance, ought, nevertheless, with the assistance of this Chapter, to be able to make a creditable report on the state of any guns he may be directed to examine. An incompetent inspector can of course shield himself from the responsibility of any possible accident by always reporting guns in which he may find any defect whatever for exchange or repair, but it is obvious that such an invariable sentence (though liable to be reversed by higher authority), would be attended with much inconvenience to the service and expense to the country.

Memorandum of examination.

When a gun is passed into the service it is marked with the broad arrow in front of the vent, and a "memorandum of examination" is sent with it. In this memorandum information is given which is of the greatest assistance to an inspecting officer, viz., the material of the bore, and, in the case of the muzzle-loading ordnance, a short description of the construction, with a wood-cut showing the gun in section. The

* This chapter is to be read in connexion with the special circular on the "Inspection on service of rifled guns," W.O. 15/11/70, which it is intended more fully to explain.

defects in the gun at the time of *its issue*,* the number of rounds it has fired, and the subsequent examinations are also stated.

Guns when to be examined. In addition to the annual and special examinations, all rifled guns will, as far as possible, be examined regularly after the following periods of service :—

9-inch and heavier calibres, after every 50 rounds with projectiles.

8-inch, 7-inch muzzle-loading and breech-loading, and 64-pr. muzzle-loading, after every 100 rounds with projectiles.

64-pr. breech-loading and smaller guns, after every 150 rounds.

Before proceeding to examine a gun the inspector should be in possession of the "memorandum of examination" which accompanies it.

Preparing a gun for examination. The bore should be thoroughly cleaned, as it is not possible to detect small defects, which may sometimes be of importance, if the bore be in a rusty or very greasy state. If care has previously been taken in keeping a gun tolerably clean, it will probably be sufficiently prepared for examination by washing, brushing, and drying with tow or a clean sponge-head. If, however, there be hard rust which will not yield, or a thick coating of lacquer or grease, the bore may be cleaned either by firing, if circumstances admit, one or two scaling charges, about one-third the full service charge, without projectiles, which will usually loosen the scale, or by the use of hot water and potash, in the following manner :—

Method of cleaning with potash water. About a gallon of boiling water is poured on one pound of black American potash, and an old sponge covered with a canvas cap, or some substitute to make it tight to the bore, is dipped into the solution. The bore is then rubbed till the dirt is loose, when the hard brush will remove it; it is then wiped dry with tow, &c., and slightly oiled. The potash water must be used very hot, and the sponge must be very tight, or the process is ineffectual. If the dirt be very thick in the small grooves of the Armstrong guns, a common pricker with the point filed flat is useful. No sharp-edged or pointed scrapers should be employed for cleaning the bores of rifled guns; they are unnecessary, and are liable to injure the rifling.

Examining by lamp and pricker. The bore, being thus cleaned, should be examined by aid of a lamp; if the surface is slightly wet the detection of defects by this means is greatly facilitated. A sharp pointed pricker is used to ascertain the extent and position of any flaw, the stave being graduated in inches so that the distance from the muzzle may be readily ascertained. Spring-searcher. A spring-searcher is also used to detect defects, and with B.L. guns in such a manner that each groove shall be traversed in succession by one of the points. Blunted pointed pricker. A pricker with "blunted point," or rather a flat edge, is also supplied, and is useful in searching the defects in coiled barrels.

If only such defects are discovered as are entered in the "memorandum of examination," it will not be necessary to take gutta percha impressions; except in the case of the powder chamber and the seat of the shot of M.L. guns, in which it is possible that a crack may exist too fine to be easily detected from the muzzle. Impressions should, however, be taken if there are any new defects, or if any old ones have materially increased.

Defects common to all materials. There are certain defects to which all guns are liable, such as "tool marks," or irregularities in the boring and rifling during manufacture; "dents" or "abrasions," caused by the bursting of a shell in the bore;

* *See* page 113, Chapter VII., &c. The position of defects developed on service are noted in a similar manner.

and "wearing at the sides of the grooves," from the friction of the studs of the projectile.*

Defects in wrought-iron barrels. However carefully iron may be selected and worked, imperfections of weld are characteristic of the material, and it is impossible to obtain a number of barrels perfectly free from them.

These imperfections form by far the majority of defects found in coiled barrels on service, and, as a rule, existed in the barrel when issued, and are of no consequence unless there is reason to believe that they have increased considerably.

The following are the names given to the various defects in wrought-iron barrels:—

"Coil marks," where the line of coil running round the barrel is visible, the weld not being quite perfect; but in this case the defect has no appreciable depth, and is of little consequence.

"Defective welds," the same sort of defect as "coil marks," but deeper and more important; they run round the bore in coiled barrels, and along it in solid forged barrels.

"Specks," small spots and pin holes in the metal, caused by dirt in iron, blisters, &c. These sometimes occur in clusters.

"Flaws," larger defects of the same nature.

"Longitudinal cracks" are also found in solid forged barrels, caused by the gas eating into the defective welds and splitting the barrel lengthways.

"Scoring" or "Guttering" about the seat of the projectile, caused by the rush of gas through the windage in M.L. guns, occurs in the coiled barrels of heavy guns (few of which have been made), and "longitudinal cracks" are also sometimes developed.

Defects in steel barrels. In steel barrels the following defects may be found:—

"Longitudinal cracks" developing into splits.

"Scoring" or "Guttering," as above.

Sentence on barrels generally. In sentencing a gun according to the state of the bore, it is essential to discriminate between defects which are characteristic of the material, and cannot wholly be avoided in manufacture, and those which are created or developed on service, such as cracks in a steel tube. In coiled barrels the defects are numerous and generally of little importance, while in steel barrels the case is reversed; defects seldom occur, but when they do they are of great importance.

It is almost impossible to lay down any definite rules as regards the extent or depth of a defect which should necessitate the condemnation of a barrel; a great deal must be left to the judgment and experience of the inspector.

Certain defects of little importance in coiled barrels. The experience of several years has proved that flaws, coil marks, and even defective welds are of little importance in guns not exceeding the size and power of the 7-inch B.L. gun. The importance of a defect depends in a great measure on its position in the gun, one in rear of the trunnions, and still more in the powder chamber, being more dangerous than one of the same nature and extent in front of the trunnions, as the powder gas acts much more rapidly upon it, and it is liable moreover in M.L. guns to hold a piece of ignited serge. Few instances have occurred in which defects in coiled barrels have caused accidents or have increased

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* The material of which the barrels are made has for some years past been stamped on the muzzle, and is also entered in the "memorandum of examination."

in any material degree after issue, unless they exist in the powder chamber, and for this reason no guns have been issued for some years past with any defect except of the most trifling character in that part of the bore.

Sentence on coiled barrels.

Unless there is reason to believe that there has been some material change from the former state of the defects, a gun with a coiled barrel need not be condemned. Speaking generally, the depth of a defect is of more importance than its extent, but, should a defective weld run *right round* the bore, the gun would be liable to part at that point, and must be considered unserviceable. The best method of testing a gun is to take an impression of the defect, then to fire a few rounds and take another impression; if on comparing these impressions the defect does not appear to have increased the barrel may be considered as serviceable.

Longitudinal cracks in barrels. (*a.*) Coiled.

It has been found that in M.L. guns having coiled iron barrels (64-prs. and a few of the heavier natures, *see* page 156), the tube is liable to split in the chamber in continuation of the edge of one of the grooves. This necessitates the provisional condemnation of the gun, and has, together with the difficulty of getting the material sound, led to the abandonment of coiled iron for the barrels of all, except the converted guns, in which there is a peculiar gas escape to indicate when the breech portion of the inner tube is split.

(*b.*) Solid forged.

In solid forged barrels a flaw running lengthways has a tendency to develop into a crack, especially if it occur in the powder chamber. If the inspector finds a case of this kind he will put the gun aside, but he will endeavour to discriminate between this and a mere streaky line, which is unimportant.*

(*c.*) Steel.

A few instances have occurred in which steel tubes have split on service from the bursting of a shell inside the bore ; in two of these the tube split at the muzzle. In cases where steel barrels have split in M.L. experimental guns when being tested for endurance, the crack has commenced at the edge of one of the grooves (as in coiled barrels) and extended into the powder chamber ; so far as the experience of the department goes the crack has never originated in the vent. As it is very possible that a crack in this part of the bore, should it exist, might be so fine as not to be visible from the muzzle, it is essential that impressions in gutta percha should in all cases be taken of the chamber of rifled M.L. guns, as before stated. Should a crack be discovered the gun must be provisionally condemned.

Scoring.

"*Scoring*" commences very early in large guns; at first it is only a mere roughness, which gradually increases in depth, and forms lines along the bore; but it is not till a gun has been fired very considerably that it becomes of importance. The gutta percha impressions of deep scoring have been said to resemble the bark of an old elm tree, the metal being eaten away into irregular furrows and ridges. Even when it has reached this extreme case, however, scoring has not caused the destruction of the gun, though in some instances acting like a wedge on the corner of a groove it has split the tube at that part. Some experimental guns, excessively scored on the upper side of the bore, have been turned over, vented, and sighted on the under side, but this has not been found necessary until the gun has been used more than is probable under ordinary circumstances.

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* The only guns having solid forged barrels are some 7-inch, 20-pr., 13 cwt., and 12-pr. B.L. and a few M.L. guns (*see* page 57).

Wear in grooves.

A little rubbing at the side of the grooves from the friction of the hard studs is of no importance, unless the metal be set up into the bore, in which case it can be filed down.

Sentence of guns in which a shell has burst.

All guns are liable to injury from shells bursting in the bore, and in one or two instances muzzles have been blown off from this cause; but generally the only result is to cut up and graze the bore more or less. It is found that such injuries seldom interfere with the efficiency of the piece, and an armourer can generally file down any metal set up in the bore; but should the inspector consider that the bore is so much cut up as to interfere with the shooting of the piece, or with its safety, it will be provisionally condemned.*

Vents, how to be examined.

The vents of rifled M.L. guns will be inspected in the same manner as is laid down for cast-iron ordnance, viz., by scraping, removing the "choke" † (if there be one) with the rimer, gauging, and taking a clean impression of the bottom.

Effect of service on vents of rifled M.L. guns.

The effect of service on a vent is seen either by a gradual increase to the channel of the vent itself, by an irregular wearing away of the bottom, by the metal of the vent setting up, and the gas forming a hollow ring round it, or by fissures or hair lines radiating into the metal of the bore from the edge of the vent bush.

Not much experience hitherto.

Hitherto there has been but little experience of the effect of much firing on the vents of heavy guns, except in the case of experimental guns, many of which have been vented in an experimental manner. It is therefore but little known how far it is safe to allow them to become worn, and until further experience is acquired the following directions are laid down for the guidance of examiners:—

No gun on service of 9-inch or lesser calibre will be ordered for re-venting on account of increase to the size of the vent itself after the "choke" is removed, unless the ·3-inch gauge passes down, nor for irregular wear at the bottom unless the cavity measures ·5-inch in diameter at the distance *up the vent* of ·25-inch measured on the impression. The gun will not be ordered for re-venting on account of a hollow ring formed round the vent-bush, unless it be at least ·1-inch in depth or width, or unless it be irregular and jagged, so as to be likely, in the opinion of the inspector, to retain a piece of cartridge. No gun will be condemned on account of *hair-lines* radiating from the edge of the vent, unless the defect be 1 inch in length; except when it is directly to the front or rear, in which case it might possibly develop into a crack along the barrel, and then the limit for condemnation will be ·5 inch. These measurements are to be taken from the *edge* of the bush. Heavier guns than the 9-inch will be treated exceptionally.

Probably rifled M.L. guns will seldom require re-venting.

It is expected that the above directions will, to a great extent, prevent the necessity of re-venting rifled guns on service, and it is important to attain this object as it has been deemed advisable for the present to restrict to Woolwich, Malta, Bermuda, Portsmouth, Devonport, Hongkong and Esquimalt, the issue of venting tools for this class of ordnance.

Wedge and converted guns.

Converted guns and wedge B.L. guns being specially vented, and the latter exceptionally bushed, can only be re-vented and re-bushed at Woolwich.

Breech fittings.

The breech-screw should be tested with the steel *straight-edge*, issued for the purpose, in order to ascertain that the face is quite flat and true;

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* This is a condition of which the Royal Gun Factories have had considerable experience, and it is advisable, if time and circumstances admit, to refer a doubtful case to the Superintendent, through the proper channel.

† The "choke" is caused by the setting in of the copper at the bottom of the vent, thereby narrowing the channel.

if it is bulged or uneven it should be filed, as otherwise the bearing against the back of the vent-piece will not be even all round, and it will be liable to split.* Breech-screw.

The thread should be hammered with a wooden mallet to see whether it is cracked, and the cracked portion (if there be any) must be cut off, and the ends bevelled off with a file. There is plenty of spare thread, so that about a quarter of it may be removed without rendering the screw unserviceable. The injured portion of the thread, if not removed, would be liable to break off in the gun and cause the screw to jam, as well as injuring the thread in the gun.

Lever, tappet, and keep-pins. The lever and tappet should be sound; the lever handles of naval guns are sometimes broken off, but the lever can still be used in this state though not so conveniently. The keep-pins must be sound.

Vent-piece and breech bush, copper. The vent-piece is the most important fitting, and should be perfectly sound, neither cracked nor bulged. The back and sides, when tested by the straight-edge, should be quite flat and true. The fracture of vent-pieces is frequently owing to the back not being true to the face of the screw. The copper ring on the vent-piece must be sufficiently high to prevent the action of the gas on any part of the iron. If necessary it should be refaced with the proper instruments (*see* Table, page 97).

Detailed instructions are contained in the boxes of implements issued for refacing and renewing both the vent-piece copper ring, and the breech bush copper. In the operation of refacing, only just sufficient copper must be removed to render the angle face quite smooth and true.

The vent-piece copper ring can be repeatedly refaced until the angle face and the back edges meet. After this it can be removed by striking it a few smart blows with a hammer on the cone face, when it is so expanded that it flies off. The new one is put on by hand, and the vent-piece having been placed in the gun front to the rear, the ring is forced on by screwing up the breech-screw. It is well to place one of the guide blocks in the face of the breech-screw to prevent its injuring the copper.

The breech bush copper can be refaced from time to time as it wears on service until the angle face and the back edges meet; it must then be bored out and renewed as detailed in the instructions above referred to, and briefly described at page 61.

Refacing 7-inch vent-piece. The angle face of the 7-inch vent-pieces should be flat, and should work truly against the cone on the end of the barrel, and the "nose" should fit closely (but not too tightly) into its place, or the tin cup will be liable to be forced in between it and the barrel and cause the vent-piece to jam. Should it not fit closely, the edge of the face must be hammered gently so as to set it out all round, and the "nose" afterwards angle faced in the usual manner.

Renewing breech bush of 7-inch and wedge guns. The bush of a 7-inch or a wedge gun will be sentenced to be renewed if found to be so much expanded that the gas can escape between it and the tin cup. In the case of the 7-inch gun the thin iron bush only is to be renewed if the gun be double bushed; the operation is more difficult than that of rebushing the smaller natures with copper, and a very strong set of facing implements is issued for the purpose. It does not, however, require to be frequently done, as the iron bush, protected by the tin cups which *must* always be used with this gun, lasts a long time.

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* An officer in charge of B.L. guns should see that the face of the breech-screws and the back of the vent-pieces fit evenly together. Two vent-pieces were split at two successive rounds from one gun during a field battery's practice this year, and the Board ordered to report on the matter, attributed the accident *to the uneven face* of the *breech-screw*, and considered that the men of the detachment working the gun were not to blame.

Wedge guns being bushed with steel, can only be repaired in the Royal Gun Factory, and no implements are issued for the purpose.

Renewing copper vent bush.

The copper bush in the neck of the vent-piece should be examined with a probe to see that it is in good order, and that the gas has not made its way in between the pieces of which it is composed and displaced them, this can be done with a wire having a small piece bent at a right angle at one end, and filed to an edge so as to catch in any aperture when drawn up the side of the vent channel. The vent should also be gauged, and if (after being rimed out) the $0''\cdot 3$ gauge passes down it should be rebushed, as the friction tube would be liable to come out without being fired when the lanyard is pulled.

In boring out the old bush a bearing can be obtained for the drill by lashing a handspike across the wheels and performing the operation with the vent-piece placed in the gun. Care must be taken to drill right down to the bottom of the copper before removing the screwed piece at the top, otherwise some difficulty will be found in removing the lower piece (or pieces). The bush is to be renewed from the spare ones issued for the purpose in the manner described at page 63.*

Examination of angle of vent channel.

The angle of the vent channel is the place where the greatest amount of wear takes place, and a cavity is formed there by the action of the gas. This must be examined with a probe to ascertain its depth and extent, but it does not necessitate the condemnation of the vent-piece, unless it has become so enlarged as to be considered dangerous by the examiner.

Cross-head.

The cross-head should not be loose, as instances have occurred in which it has been broken off by firing.

Wedge and stopper.

The wedge and stopper of the breech-loading wedge guns should be examined with the straight-edge for the truth of their various surfaces. The studs of the stopper should be filed if at all burred. The locking-pin should not be bent, and the whole arrangement should be in easy working order.

Exterior of guns.

Very considerable defects may exist on the exterior of a wrought-iron gun, without the strength being affected. Hardly an instance has yet occurred with the present class of rifled ordnance of the exterior of a gun failing, unless the interior has first shown signs of weakness, or been strained in an extraordinary manner, except in the case of the B tubes of heavy guns. These have opened in come instances circumferentially, but this defect has been proved by experiment not to interfere with the safety and serviceability of the gun. If it be found that a shell has burst in a bore, the exterior should be thoroughly scraped with old swords, and cleaned (with potash water, if necessary) in order to ascertain whether it is perfectly sound. Wrought-iron guns, and more particularly the breech-loaders should be examined in order to show any shifting of the coils which may have occurred. If any considerable movement of the coils has taken place the gun should be put aside ; but a slight shift, which is sometimes perceptible when the gun is first used, and which has gone no further afterwards, or any exterior defect which does not increase on firing, may be disregarded. Unless there be reason to suspect damage on the exterior, it will not be necessary to scrape the whole of the paint off whenever a gun is examined. Large defects on the exterior are noted on the "Memorandum of Examination."

Gutta percha impressions.

Impressions in gutta percha of portions of the bores of rifled guns are taken with the special instrument issued for the purpose (see page 98), but should this instrument not be available, or impressions be required of the whole length of the bore, wood blocks (§ 1625) can be used.

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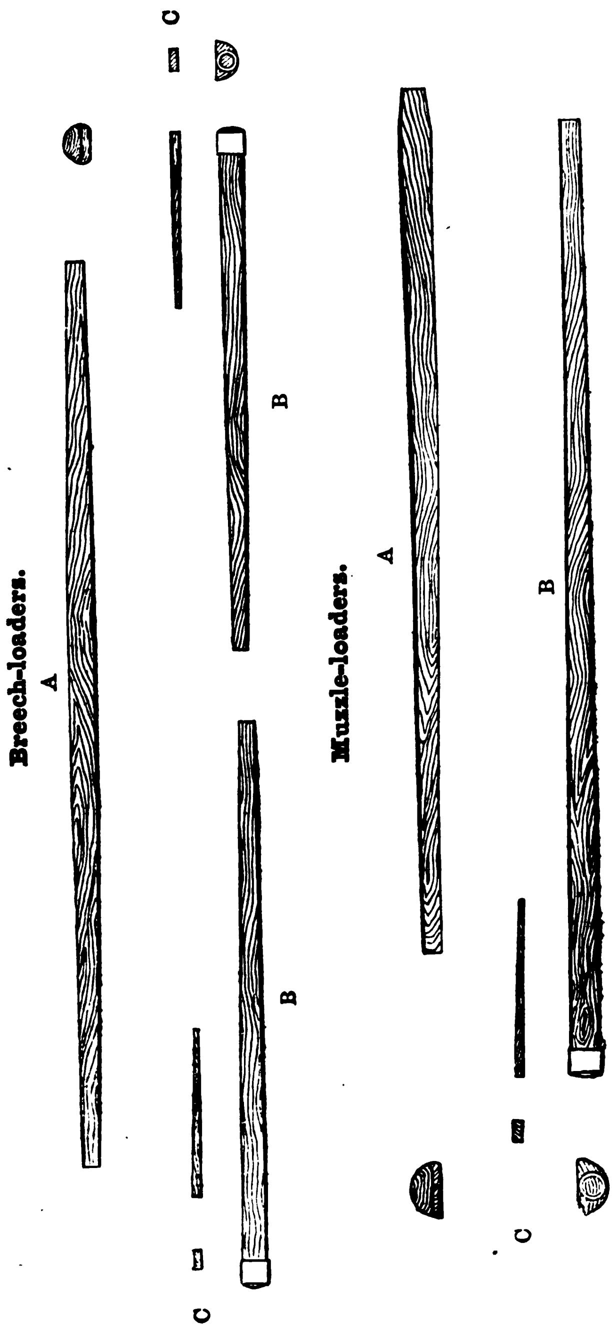
* The necessary implements are carried in the special tool chest included in the equipment of B.L. batteries.

These blocks are shown in the annexed woodcut, they can be made by any carpenter, but require some practice to work with, and cannot be relied upon to give as perfect impressions as the instrument. For this reason it is customary in the Royal Gun Factories always to take impressions of the powder chamber of guns with the instrument, in addition to the long impressions taken by means of the blocks.



Wood Blocks for taking Impressions of the Bores of Guns. Scale ½ inch = 1 foot.

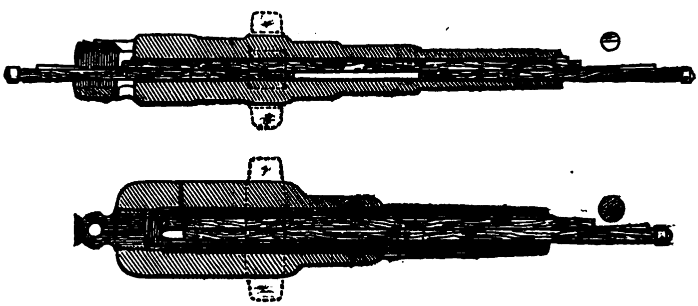
Method of using wood blocks.

The blocks A (tapering from the centre for B.L. guns, and from the breech for M.L. guns) with their wedges B should be made to suit the diameter of the bores to be taken, leaving room for about 0·25 inch of gutta percha when the wedge or wedges are driven home, and proceed as follows:—

A sufficient quantity of gutta percha, having been softened in water just under the boiling point, is well kneaded and worked to expel the air and water, and is laid along the block A, which has been previously prepared by rubbing it over with a little soft soap. The gun is so placed that the impression required will be taken upwards, the block A is inserted into the bore, and the wedge B (if a B.L. gun by simultaneous blows at both ends) is driven well home with mauls; a small wedge C is then forced between the ends of the blocks A and B.

Method of using the Wood Blocks for taking Gutta Percha Impressions of the Bores of Guns.

Scale $\frac{1}{48}$ size.



This can easily be withdrawn in about 10 or 15 minutes, according to the weather, when the impression has become cold, and thus gives slackness to the wedge B and the block A, which are withdrawn in the order named together with the impressions, which can be readily removed from the block, being prevented from sticking by the soft soap.

Before impressions are taken the bore should be quite clean but slightly greasy; if quite dry the gutta percha will adhere to it, and the impression be damaged in removal.

Impressions of vents.

Impressions of vents will be taken with the improved instruments for taking impressions of bores, the plates for which are now fitted with ends to suit the chambers of guns (*see* § 2032), or they may be taken with the instrument provided among the tools for venting ordnance, if that instrument and the proper blocks are at hand.

Impressions to be labelled.

When an impression is forwarded with a return for report or decision a label will be gummed to the back, showing the *name of the station*, the *date of taking the impression*, the *nature and number of the gun*, and the *position of the defect* (if it be in any part but the vent), taken according to the directions previously given (*see* page 113), *and the direction of the muzzle.* The impression should be reduced to the smallest dimensions compatible with showing the whole of the defect.

Preservation of Guns and their Fittings.

Painting.
§ 1035.

The bores of guns are lacquered.

20-pr. B.L. guns and upwards are painted on the exterior with one coat of "Pulford's magnetic paint," the guns being previously well cleaned, but all other wrought-iron field guns are browned for land service

only, as paint would be removed by the rough usage to which these guns are liable. The operation is as follows :—

Browning.

1. Steam the gun for 10 hours, then wash with a lye of potash (1 lb. black potash to 1 gallon of water); repeat until the grease is thoroughly eradicated.

(A.) If there be no convenience on service for the performance of the steaming process, simple washing may have to be employed instead. The whole object is to get rid of oil which may remain on the surface of the iron, and hence the water should be as hot as can be borne by the operator, who will rub vigorously all over the exterior surface with a clean hard brush; a little hard soap should be used, and the water should be frequently changed so as to ensure its perfect cleanness. This washing and scrubbing with soap and hot water must be repeated at least three times; then wash the gun with the lye of potash as aforesaid.

(B.) Repeat the process A, consisting of three washings and scrubbings with soap and water, and of one washing with the lye of potash several times; to obtain perfect cleanness may require many repetitions of the whole process, and care must be taken not to touch the gun with any fatty matter or even with the hand as it may take hours of washing to wholly remove the effect.

2. Wash with hydrochloric acid and water (equal parts) to remove oxide, then wash with clean water and wipe dry.

3. Apply browning mixture with a sponge, and let stand for 12 hours in a temperature not less than 60° or more than 100°; then rub off rust with scratch-card and brush. The browning mixture is composed of the following :—

Tincture of steel	2 parts.
Nitric acid -	1 „
Blue vitriol -	1 „
Spirits of nitre -	$1\frac{1}{2}$ „
Spirits of wine -	$1\frac{1}{2}$ „
Soft water -	32 „

4. Apply mixture, let it stand six hours, rub off rust.
5. Repeat No. 4.
6. Apply mixture, let stand six hours, then boil five minutes in a lye of potash (1 lb. potash to 2 gallons of water), then rub off rust.
7. When cold, repeat No. 4.
8. Repeat No. 4.
9. Apply mixture, stand six hours, then boil as in No. 6 operation, rub off rust, then coat with olive oil.

Care to be taken to well sponge and dry the bore and chambers after each operation of washing, steaming, or boiling.

Stores required for browning a battery.

The following is a detail of the stores and quantities of ingredients required for browning a battery of six 9-pr. guns, or six 12-prs., viz. :—

Tincture of steel - -	4 ozs.	To be mixed in 2 quarts of soft water.
Nitric acid - - -	2 „	
Blue vitriol - - -	2 „	
Spirits of nitre - - -	2 „	
Spirits of wine - - -	3 „	
Hydrochloric acid - - - - - -		6 lbs.
Earthernware pan to hold 6 quarts, for hydrochloric acid		1
American potash - - - - - -		6 lbs.
Wooden pail for do. - - - - -		1
Oil - - - - - - - -		1 gill.
Sponge cloth for do. - - - - -		1

Sponge to apply the browning mixture - - -	1
Flat brush to apply the hydrochloric acid - -	1
Scratch-card to rub the surface of the gun between the coatings - - - - - -	6 ins.

Bronzing. The exposed gun-metal portions of all the tangent and drop sights are protected from the influence of the atmosphere by "bronzing," as follows:—

1st. Polish the parts well and heat them over a spirit lamp or gas.

2nd. Polish with a brush and black lead, to remove all grease, &c.

3rd. The bronzing mixture is then applied to the heated metal. It consists of—

Bichloride of platinum - - -	2 parts.
Corrosive sublimate - - -	1 „
Vinegar - - - - -	1 „

4th. The parts are next dipped into boxwood saw-dust to dry them, and then again polished with black lead to give a body to the colour. The figures, which are left bright, are rubbed with emery cloth, and the whole is finally varnished with shellac and methylated spirits.

The steel tangent bar, screw trunnion sight, and all trunnion sight leaves are blued.

Blueing. Blueing consists simply in covering the surface with a thin film of oxide sufficient to give the article a deep blue colour and to prevent further oxidation from exposure to the atmosphere. This is easily effected by polishing bright the surface of the article, and heating it to about 550° until it assumes a blue colour and then allowing it to cool gradually. A sand bath is generally used in order to obtain a uniform heat, and the bar, &c. is taken out from time to time to watch the change of colour and to prevent its going too far.*

Preservation of Rifled B.L. Guns.

§ 1504. The course which has hitherto been followed with regard to rifled B.L. guns when laid up in store, or mounted in such positions as to be rarely or never used, viz.: coating the bore, screws, slot, &c. with grease composed of seven parts of tallow to one of white lead, and closing the muzzle and breech ends of the barrel, and the end of the breech-screw with wooden plugs, will be discontinued.

The bores of such guns will, in future, be lacquered with black lead lacquer, composed (as laid down in War Office circular, No. 930, 21st October 1865) of—

	lbs.	ozs.
Black, lamp, dry - -	0	12
Lead { black, dry - -	24	8
Lead { red, dry - - -	6	12
Oil, linseed, raw - - -	9	0

The breech-screw and bright parts about the guns will be coated with a composition of—

Tallow - - -	3 parts.
Oil, lard - - -	1 „

Lead, white, about 1 lb. to a gallon.

The parts which can be removed being laid up in store.

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* The temperature may be judged by the colours, which successively appear on the surface of the steel at various low temperatures, viz. :—

At 450° F. the steel becomes a straw colour, 475° an orange or gold, 500° brown, 350° purple, 555° violet, 580° blue, 610° white, and at 625° red.

The quantity of lacquer authorised to be used for every six guns is,—

		lbs.	ozs.
7-inch and 64-prs.	-	3	0
40-prs. (screw or wedge)	-	2	4
20-pr. and 12-prs.	-	1	2
9-pr. and 6-prs.	-	0	12

The quantity of grease allowed for breech-screws, &c. for every ten guns is,—

7-inch	-	20 lbs.
64-pr.	-	15 „
40 „ (screw or wedge)	-	15 „
20 „	-	10 „
12 „	-	7½ „
9 „	-	7½ „
6 „	-	7½ „

Muzzle and breech plugs will therefore be no longer required for these guns.

The lacquer above described can be removed in a few minutes by brushing the bore with hot potash solution (see page 179).

*Directions for the Preservation of Sights and Fittings of Rifled M.L. Guns on service.**

Preservation of sights. When mounted in exposed positions the whole of the sights should be removed from the guns and kept in store, the holes in the guns being filled with a plug of greased tow to keep out the rain and dirt. These plugs can be readily removed when it is required to fit the sights to the guns, and particular attention should be paid to the prevention of rust or grit accumulating in the sight recesses.

The set-screw for clamping the centre hind sight, not being removeable from the gun, should be tested to see that it works freely.

The sights themselves should be kept clean, free from grit, and oiled; the "sliding leaf" and "elevating nut" of the tangent sights, as well as the "collars" of the drop centre fore and trunnion sights, should have free play.

The exposed portions of the sights are "bronzed" (see page 188), if made of gun-metal, and "blued" if of steel. This is done to preserve them from corrosion, and on no account are these parts to be burnished or cleaned in such a manner as to remove the bronzing or blueing more than it is of necessity worn off by fair wear.

Plates, metal, elevating. Metal elevating plates are marked "R." and "L." for the side of the gun to which they belong, looking from breech to muzzle. They are fastened to the gun by four screws, and are fitted with steel pivots and keep-pins, by means of which the elevating arcs of the carriage are attached to the gun.

These plates are removed for transport, and the holes in the gun fitted with preserving screws.

Preserving screws. Guns fitted for land service have the "friction tube pin" holes and the "guide-plate" hole filled by preserving screws, and it is advisable that these screws should be occasionally removed and oiled to prevent their becoming fixed by rust.

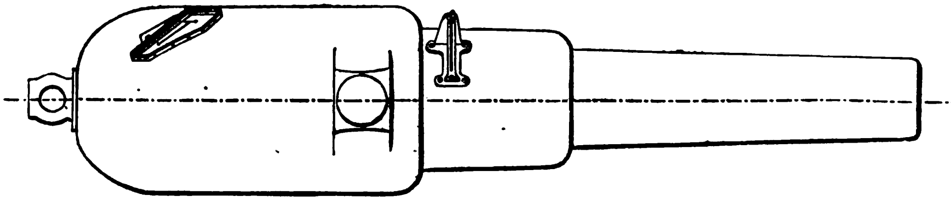
* Published by direction of the Surveyor-General of the Ordnance, War Office, December 1870.

Instructions for adjusting the "Moncrieff" Sights.

Wrought-iron M.L. Gun, 7-inch 7 tons, R.

Sketch, showing position of Moncrieff Sights.

Scale $\frac{1}{32}$.



The tracing shows the service position of the sights when finally adjusted.

To fix the sights on the gun, first take out the preserving screws and thoroughly clean the fitting surfaces of both gun and sight brackets; then screw on sights, as in tracing (using the thick screws for the reflector), taking care that the screws are sent firmly home, otherwise the shock of firing will loosen the sights, destroy the adjustment, and perhaps break the glass.

When the sight brackets are firmly fixed, lay the gun accurately by the tangent sights (at zero) on a fixed object sufficiently far off to render the lateral distance between the two systems of sighting inappreciable; then observe whether the intersection of the cross-lines (*i.e.*, the centre of the top of the **T**) upon the reflector is in line with the zero of the fore-sight and the object, also whether the vertical line (the upright of the **T**) on the glass coincides with the centre line of the fore-sight, indicated by the extremities of the longer pins. If both these conditions are fulfilled, the sight is in adjustment; if not, the glass must be shifted.

To move the glass, unscrew the metal strips round the face of the frame, and take out the narrow frame cushions of india-rubber or other elastic material, and also the wood packing, leaving the glass in the frame; then adjust the glass by paring down the old pieces of wood, and wedging up with fresh ones, as may be required; when correctly and firmly fixed, replace the cushions, and screw in the metal strips again; the sight will then be ready for use.

There are four fine lines on the edges of the mirror, and four on the frame; the relative positions of these should be accurately noted after the final adjustment of the sight, so that any shifting may be readily detected.

An Annual Return of the State of Rifled Ordnance, and of the Number of Rounds fired from each Gun.

18____.

Descriptive Marks.			Weight.*				Nature.	Date of last Examination.	Condition of Bore, specifying any important Flaws or Dents.	Sentence.			Number of Rounds fired at Date of Return.												Number of Rounds fired since last Examination.†	In Store, or whether mounted, and where placed, in Ship or Fortress.	Received from		Returned or issued to		Condition of.						Remarks.
													Blank.			With Projectile.																			Vent.		
										A	R	+	Reduced.			Battering or Distant.			Full.			Reduced.															
No.	Numeral of Pattern.	Initial of Factory, and Date.	Tons.	Cwt.	Qrs.	Lbs.				Serviceable.	Repairable.	Unserviceable.	Previously reported.	Since.	Total.	Previously reported.	Since.	Total.	Previously reported.	Since.	Total.	Previously reported.	Since.	Total.			Station, &c.	Date.	Station, &c.	Date.	Breech-screw.	Vent-piece.	Wedge.	Stopper.	Through Gauge.	Size at ·25-inch from Bottom.	

* Under 100 cwt. give the full weight in cwts.; 5 tons and upwards in tons. See § 1081, Changes in Ordnance, &c.

† In the forms at present in use this column is blank, but it is to be filled up as shown here.

LIST of TOOLS required for the CLEANING and EXAMINATION of the various natures of RIFLED ORDNANCE.

—	Muzzle-loading.							Breech-loading.								Remarks.
	12-in.	10-in.	9-in.	8-in.	7-in.	64-pr.	7-pr.	7-in.	64-pr. (Wedge).	40-pr.	40-pr. (Wedge).	20-pr.	12-pr.	9-pr.	6-pr.	
Bits, vent - Armstrong	—	—	—	—	—	—	—	1	—	1	—	1	1	1	1	
Bits, vent - 23-in.	1	1	1	1	1	—	—	—	—	—	—	—	—	—	—	This is the service vent bit for heavy guns.
Bits, vent - 12 ,, *	—	—	—	—	—	1	1	—	1	—	1	—	—	—	—	
Brace, armourers'*	1	1	1	1	1	1	1	—	1	—	1	—	—	—	—	
Brushes, gun 12-in.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Brushes, gun 10 ,,	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
Brushes, gun 9 ,,	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	
Brushes, gun 8 ,,	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	
Brushes, gun 7 ,, *	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	The same brush that is issued for the 56-pr. cast-iron gun.
Brushes, gun 64 and 80-prs.*	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	Ditto ditto for the 42-pr. cast-iron gun.
Brushes, gun 40 ,,	—	—	—	—	—	—	—	—	—	1	1	—	—	—	—	
Brushes, gun 20 ,,	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	
Brushes, gun 12, 9, and 7 pr.	—	—	—	—	—	—	1	—	—	—	—	—	1	1	—	
Brushes, gun 6-pr.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	
Gauges, vent, set of 4 long	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	
Gauges, vent, set of 4 short *	—	—	—	1	1	1	1	—	1	—	1	—	—	—	—	
Instruments, taking impressions of bores No. 1	1	1	1	1	1	1	—	1	1	1	1	—	—	—	—	
Instruments, taking impressions of bores No. 2	—	—	—	—	—	—	1	—	—	—	—	1	1	1	1	
Lamp, tin, with rod *	1	1	1	1	1	1	—	—	—	—	—	—	—	—	—	
Plates for instruments taking impressions of bores. 12-in.	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
Plates ... 10 ,,	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	
Plates ... 9 ,,	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	Plates are not required for the 40-pr. or 6-pr., as the frames answer the purpose.
Plates ... 8 ,,	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	
Plates ... 7 ,,	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—	
Plates ... 64-pr. W.I.	—	—	—	—	—	2	—	—	1	—	—	—	—	—	—	
Plates ... Converted 64 and 80-prs.	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—	
Plates ... 20 and 16-prs.	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	
Plates ... 12, 9, and 7 pr.	—	—	—	—	—	—	1	—	—	—	—	—	1	1	—	
Pot, softening gutta percha *	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Pricker, common, with pan*	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Ditto (with blunted point)	—	—	—	—	—	1	—	1	1	1	1	1	1	1	1	
Rimers, vent - 22-in.	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	This is the same that is issued with venting tools for heavy ordnance.
Rimers, vent - 15 ,, *	—	—	—	1	1	1	1	—	1	—	1	—	—	—	—	
Scrapers, vent, half-round 24 ,,	1	1	1	—	—	—	—	—	—	—	—	—	—	—	—	
Scrapers, vent, half-round 14 ,, *	—	—	—	1	1	1	1	—	1	—	1	—	—	—	—	
Straight-edge, testing breech fittings	—	—	—	—	—	—	—	1	1	1	1	1	1	1	1	
Swords, old *	2	2	2	2	2	2	1	2	2	2	2	2	2	2	1	

* Articles marked thus * being among the tools for examining cast-iron ordnance, should not be demanded by officers applying for tools for examining wrought-iron ordnance, if they have already been supplied with a set for examining cast-iron ordnance.

LIST of VENTING TOOLS for RIFLED MUZZLE LOADING GUNS.

DESCRIPTION.	No. 1 Set.	No. 2 Set.	REMARKS.
Bar, iron, with spring and metal collar	1	1	
Blocks, wood, for taking impressions of vents. 7″, 8″, 9″, 10″, 11″, and 12″ (one to each calibre).	6	–	
„ 64-pr., Mark I.	1	–	
„ „ „ II. and III.	1	–	
„ „ and 80-pr. converted	1	–	
Block, metal, ditto 40-pr.	–	1	
„ 16-pr. and 25-pr. The same block answers for these two guns.	–	1	
Braces, iron, armourers	1	1*	
„ drilling, large	1	–	
„ ratchet, 12-inch	–	1	
Brushes, gun, soft	1	1*	
Chisels, hand, flat	5	5*	
„ gouge	1	1*	
„ gravers	3	3*	
Collars, cast-iron, for muzzles of guns 8″ and upwards	7	4	
Cutters for metal heads. 7″, 8″, 9″, 10″, 11″, and 12″ (one to each calibre).	6	–	
„ 64-pr. W.I. guns	1	–	
„ 64-pr. and 80-pr. converted	1	–	
„ 40-pr. and 25-pr.	–	2	
„ 16-pr. and 9-pr.	–	1	
„ 7-pr. 224 and 200 lbs.	–	1	
„ 7-pr. 150 lbs.	–	1	
Drifts for taking out old vents	5	2	
Drills, cone	2	2	
„ hollow	2	2	
„ venting, drifting	5	2	
„ venting, tapping	5	2	
Files, bastard, flat, taper, 16-inch, with handle	1	1*	
Frame, iron, for cutting off ends of vents, with adjusting bar and extenders.	1	1	
Gauge, vent, ·22 inch	2	1	
Hammers, hand	2	2*	
Heads, metal, for cutters. 7″, 8″, 9″, 10″, 11″, and 12″ (one to each calibre).	6	–	
„ 64-pr., with extra stop	1	–	
„ 64-pr. and 80-pr. converted	1	–	
„ 40-pr., 25-pr., and 16-pr. (one to each calibre).	–	3	
„ 9-pr. and 7-pr.	–	1	
Instruments for taking impressions of vents	1	1	
Levers, iron, for working bar	2	2	
Machine, drilling, with chain complete	1	1	
Pans for instruments for taking impressions of vents. A, large	1	–	
„ B, small	1	–	
„ C, converted guns	1	–	
„ 40-pr.	–	1	

N.B.—Those marked * are identical in both sets.

List of Venting Tools for Rifled Muzzle-Loading Guns—*continued.*

Description.			No. 1 Set.	No. 2 Set.	Remarks.
Rimers	cone		2	2	
	mouth of vent (Sea Service)		1	1*	
	vent	long, 22-inch	1	–	
		short	3	1	
Saw, with frame, 14-inch			1	1*	
Spanner for nuts on frame			–	1	
Stave for brush, Turk's head, and fitting			1	1	
Taps	$1\frac{1}{8}''$ new thread		3	3	
	$\frac{5}{8}''$ fine "		–	3	
Wire, directing			1	1	
Wrenches	cutter		1	–	
	socket		1	1	
	tap		1	–	
	taps and vents	large	–	1	
		small	–	1	
	vent		1	–	

N.B.—Those marked * are identical in both sets.

APPENDIX.

Mode of obtaining Velocity and Energy of Projectiles.—Table of Velocities of Heavy Guns.—Table of Energy of Projectiles fired from Heavy Guns.—Table of Guns with Ammunition, &c.—Range Tables.

APPENDIX.

MODE OF OBTAINING VELOCITY AND ENERGY OF PROJECTILES.

Electricity is the agent now employed for measuring the velocity of any projectile, and the method of doing so may be generally described as follows, though the details of construction and the principles involved in the various instruments differ considerably.*

Method of finding the *muzzle velocity* of a projectile.

Frames with wire stretched across them are placed at certain intervals in front of the gun so that the shot shall cut the wires successively, thereby interrupting the electric currents which pass through them and the instrument connected with them. A record is thus obtained in the instrument of the precise instant at which the projectile passes each frame. The time occupied in passing from one frame to the other is therefore known, and by dividing the distance between the frames by this time, the velocity of the projectile at a point half way between the frames is found. For instance, suppose the frames to be 120 feet apart, and the time taken by the shot in passing between them to be 0·1 of a second, then the velocity of the projectile will be $\frac{120}{0 \cdot 1} = 1{,}200$ feet a second. As the first frame must be placed some distance from the gun, to prevent its being damaged by the discharge, the velocity obtained as above is that of the projectile between 100 and 200 feet from the gun, and in order to find the velocity at the muzzle it is necessary to calculate the loss due to the resistance of the air over that space. This is done by means of a formula similar to that used for calculating the remaining velocity of a projectile at any range, being given the velocity at the muzzle. The formula employed for this purpose by Captain W. H. Noble, R.A., by whom the following tables have been calculated, is as follows:—

Method of calculating the *remaining velocity*.

$$v = \frac{V}{1 + c V x} \text{ where}$$

v = remaining velocity in feet,
V = initial velocity in feet,
x = distance from muzzle in feet,
$c = b \frac{R^2}{W}$,
R = radius of the projectile *in feet*,
W = weight „ „ in lbs.

b = a variable co-efficient depending on the form of the shot and the velocity of the projectile. Now the ogival form of head is that used for all service elongated projectiles, and for this form of projectile, and for velocities

* For a description of the common instruments in use see the following:—
Description of Navez-Leurs Electro-ballistic Apparatus, by Captain W. H. Noble, R.A. Printed by authority, 1868.
Description of the Le Boulengé Chronograph, by Lieut. C. Jones, R.A. Printed by authority, 1870.
Description of the Bashforth Chronograph, by the Rev. F. Bashforth, M.A. London, Bell and Daldy. Also R.A.I. Papers.
Captain A. Noble's Chronoscope. See Report of the Committee on Explosives, 1870.

over 1,100 feet, a second b may be supposed constant, and for all practical purposes may be made equal to—

$$0 \cdot 000063.$$

Example.

The following is an example of the method by which this formula has been used to calculate the remaining velocities given in the table.

The 9-inch R.M.L. Gun of 12 tons is fired with a projectile of 250 lbs. weight, and 8·92 inches diameter, and 50 lbs. of "P." powder, which gives an initial velocity of 1,420 feet a second. What will the remaining velocity be at 500 yards range? Here we have—

$$V = 1420 \text{ ft.}$$
$$x = 1500 \text{ ft. (500 yards),}$$
$$R = 4 \cdot 46 \text{ in.} = 0 \cdot 37166 \text{ ft.}$$
$$W = 250 \text{ lbs.}$$

Therefore,—

$$R^2 = 0 \cdot 13813 \text{ ft.}$$
$$\frac{R^2}{W} = 0 \cdot 0005525,$$
$$c = 0 \cdot 000063 \times 0 \cdot 0005525,$$
$$= 0 \cdot 00000003481.$$

Substituting these values in the equation $v = \frac{V}{1 + c V x}$ we have

$$v = \frac{1420}{1 + 0 \cdot 00000003481 \times 1420 \times 1500}$$
$$= \frac{1420}{1 \cdot 07415}$$
$$= 1322 \text{ feet.}$$

Professor Bashforth's Tables of remaining Velocities, &c. &c.

The velocity lost in 500 yards is therefore 98 feet. A small pamphlet has lately been published by the Rev. Professor Bashforth * giving the results arrived at by a long series of experiments carried on with his chronograph, with a view to the accurate determination of the resistance of the air to the motion of projectiles. The Tables in this little book will all be found most useful in solving problems in gunnery, and the two last, viz., Nos. 20 and 21 render the calculation of the remaining velocity of any projectile at ranges up to 2,000 yards very simple and expeditious. The method of using these tables is explained in the pamphlet.

Method of calculating the "*energy*" of a projectile.

Having ascertained the velocity of a projectile at any point of its flight it is easy to calculate the energy or *vis viva*, that is, the blow which it is capable of delivering at that point, from the well known formula—

$$\text{Vis Viva} = \frac{W V^2}{2 g}$$

Where W = weight of projectile in lbs.,
V = velocity in feet,
g = force of gravity (32·2).

This gives the energy in "foot pounds," a foot-pound being the blow struck by one pound falling through one foot, and to obtain it in foot-tons it is necessary to divide by 2,240, or the number of pounds in a ton.

* "Tables of remaining Velocity, Time of Flight, and Energy of various Projectiles, "calculated from the results of Experiments made with the Bashforth Chronograph, "1865–1870." London: E. and F. N. Spon, 48, Charing Cross, 1871. Also in R. A. I. Papers, Sept. 1871, Vol. VII.

Required the energy of a 9-inch Palliser shot at the muzzle of the gun

Example.

In this case—

$$W = 250$$
$$V = 1420$$
$$\therefore \text{ Vis Viva in foot tons} = \frac{250 \times (1420)^2}{4480 \times 32 \cdot 2}$$
$$= \frac{250 \times 2016400}{4480 \times 32 \cdot 2}$$
$$= 3496 \text{ foot tons.}$$

Penetration varies as the diameter.

Now it has been found by experiment that the resistance to penetration of a projectile into armour plates varies directly as the diameter or circumference, the total energy being constant. For instance, if two shot, of the same weight and moving with the same velocity have one a diameter of 10 inches, and the other only five inches, the resistance to penetration of the former will be twice that of the latter. In order therefore to find the *penetrative power* of any projectile it is customary to divide the total energy stored up in it by the number of inches in the circumference, and thus, in comparing the powers of guns, to compare the number of foot tons per inch of circumference of their projectiles. (See Table, page 200.)

In fact the total energy represents the force of the blow delivered, or the "*racking*" power of any projectile; while the number of foot-tons per inch of its circumference represents its penetrative or "*punching*" power.

For instance, the total energy of the projectile of the 12-inch 25 ton gun at the muzzle is 7,030 foot tons, while that of the 11-inch 25 ton gun is only 6,415; but the penetrative powers of the two are only as 188 to 187 on account of the difference in diameter.

Captain W. H. Noble, R.A., has embodied much valuable information on the velocities of projectiles and the penetration of armour plates, in the following reports to the W.O., viz. :—

"Reports on Ballistic Experiments," 1863 and 1865, and "Report on the " Penetration of Iron Armour Plates," 1866.

Table of Velocities of Projectiles fired with Battering Charges of P. Powder from heavy Rifled M.L. Guns.

Range.	12-inch R.M.L. of 35 tons. Charge, 110 lbs. Projectile, 700 lbs.	12-inch R.M.L. of 25 tons. Charge, 85 lbs. Projectile, 600 lbs.	11-inch R.M.L. of 25 tons. Charge, 85 lbs. Projectile, 535 lbs.	10-inch R.M.L. of 18 tons. Charge, 70 lbs. Projectile, 400 lbs.	9-inch R.M.L. of 12 tons. Charge, 50 lbs. Projectile, 250 lbs.	8-inch R.M.L. of 9 tons. Charge, 35 lbs. Projectile, 180 lbs.	7-inch R.M.L. of 6½ tons. Charge, 30 lbs. Projectile, 115 lbs.
	Velocity.	Velocity.	Velocity.	Velocity.	Velocity.	Velocity.	Velocity.
yards.	feet.	feet.	feet.	feet.	feet.	feet.	feet.
0	1,300	1,300	1,315	1,364	1,420	1,413	1,525
100	1,288	1,286	1,302	1,350	1,399	1,391	1,496
200	1,277	1,273	1,289	1,336	1,379	1,369	1,467
300	1,266	1,260	1,277	1,322	1,360	1,348	1,438
400	1,255	1,248	1,265	1,308	1,341	1,327	1,409
500	1,244	1,236	1,253	1,294	1,322	1,306	1,382
600	1,234	1,224	1,242	1,280	1,304	1,286	1,356
700	1,224	1,212	1,231	1,267	1,277	1,267	1,331
800	1,214	1,201	1,220	1,254	1,270	1,248	1,317
900	1,205	1,190	1,239	1,241	1,253	1,230	1,284
1,000	1,196	1,179	1,199	1,228	1,236	1,213	1,261
1,100	1,187	1,168	1,189	1,216	1,220	1,196	1,239
1,200	1,178	1,157	1,179	1,204	1,204	1,180	1,217
1,300	1,169	1,147	1,169	1,192	1,189	1,165	1,197
1,400	1,160	1,137	1,159	1,181	1,174	1,150	1,177
1,500	1,151	1,127	1,149	1,170	1,160	1,136	1,158
1,600	1,142	1,118	1,139	1,159	1,147	1,122	1,141
1,700	1,133	1,109	1,130	1,148	1,134	1,109	1,124
1,800	1,125	1,101	1,122	1,138	1,121	1,097	1,108
1,900	1,117	1,093	1,114	1,128	1,109	1,085	1,093
2,000	1,109	1,085	1,106	1,118	1,097	1,074	1,078
2,100	1,101	1,077	1,098	1,108	1,086	1,063	1,065
2,200	1,093	1,069	1,090	1,099	1,075	1,052	1,053
2,300	1,085	1,062	1,082	1,090	1,065	1,042	1,041
2,400	1,077	1,055	1,075	1,082	1,055	1,032	1,030
2,500	1,069	1,048	1,068	1,074	1,046	1,023	1,019
2,600	1,061	1,041	1,061	1,066	1,037	1,014	1,009
2,700	1,057	1,034	1,054	1,059	1,028	1,005	999
2,800	1,046	1,028	1,048	1,052	1,020	996	990
2,900	1,039	1,022	1,042	1,045	1,012	988	982
3,000	1,032	1,016	1,036	1,038	1,004	980	974
3,100	1,025	1,010	1,080	1,031	997	972	967
3,200	1,018	1,004	1,024	1,025	990	965	960
3,300	1,011	998	1,018	1,019	984	957	953
3,400	1,004	993	1,012	1,013	978	949	946
3,500	997	988	1,007	1,007	972	942	939
3,600	990	984	1,002	1,002	966	935	932
3,700	984	980	998	997	960	928	925
3,800	978	976	994	992	955	921	919
3,900	972	972	990	987	950	914	913
4,000	966	968	986	982	945	907	907
4,100		964	982	977	940	900	901
4,200		960	978	972	935	894	895
4,300		956	974	967	930	888	889
4,400		952	970	963	925	882	884
4,500		948	966	958	920	876	879
4,600		944	962	954	915	870	874
4,700		940	958	950	910	864	869
4,800		936	955	946	906	858	864

Table showing the Energy of Projectiles fired with Battering Charges of P. Powder from heavy Rifled M.L. Guns.

Range.	12-inch R.M.L. of 35 tons. Charge, 110 lbs. Projectile, 700 lbs.			12-inch R.M.L. of 25 tons. Charge, 85 lbs. Projectile, 600 lbs.			11-inch R.M.L. of 25 tons. Charge, 85 lbs. Projectile, 535 lbs.			10-inch R.M.L. of 18 tons. Charge, 70 lbs. Projectile, 400 lbs.			9-inch R.M.L. of 12 tons. Charge, 50 lbs. Projectile, 250 lbs.			8-inch R.M.L. of 9 tons. Charge, 35 lbs. Projectile, 180 lbs.			7-inch R.M.L. of 6½ tons. Charge, 30 lbs. Projectile, 115 lbs.		
	v.	Total Energy.	Energy per Inch of Shot's Circumference.	v.	Total Energy.	Energy per Inch of Shot's Circumference.	v.	Total Energy.	Energy per Inch of Shot's Circumference.	v.	Total Energy.	Energy per Inch of Shot's Circumference.	v.	Total Energy.	Energy per Inch of Shot's Circumference.	v.	Total Energy.	Energy per Inch of Shot's Circumference.	v.	Total Energy.	Energy per Inch of Shot's Circumference.
yards.	feet.	foot tons.	foot tons.	feet.	foot tons.	foot tons.	feet.	foot tons.	foot tons.	feet.	foot tons.	foot tons.	feet.	foot tons.	foot tons.	feet.	foot tons.	foot tons.	feet.	foot tons.	foot tons.
0	1,300	8,200	219	1,300	7,030	188	1,315	6,415	187	1,364	5,160	165·6	1,420	3,496	124·7	1,413	2,492	100·2	1,525	1,855	85·3
200	1,277	7,915	211	1,273	6,750	181	1,289	6,165	180	1,336	4,950	158·9	1,379	3,297	117·6	1,369	2,339	94·0	1,467	1,716	78·9
400	1,255	7,645	204	1,248	6,480	174	1,265	5,935	173	1,308	4,745	152·3	1,341	3,117	111·2	1,327	2,198	88·3	1,409	1,583	72·8
600	1,234	7,391	197	1,224	6,230	167	1,242	5,720	167	1,280	4,575	146·8	1,304	2,948	105·2	1,286	2,064	83·0	1,356	1,466	67·5
800	1,214	7,165	191	1,201	6,000	161	1,220	5,520	161	1,254	4,360	140·0	1,270	2,796	99·8	1,248	1,944	78·1	1,317	1,383	63·6
1,000	1,196	6,946	185	1,179	5,780	155	1,199	5,335	156	1,228	4,185	134·2	1,236	2,648	94·5	1,213	1,837	73·8	1,261	1,268	58·3
1,200	1,178	6,735	180	1,157	5,570	149	1,179	5,155	150	1,204	4,020	129·0	1,204	2,513	89·7	1,180	1,738	69·9	1,217	1,181	54·3
1,400	1,160	6,531	175	1,137	5,380	144	1,159	4,985	145	1,181	3,870	124·1	1,174	2,389	85·3	1,150	1,651	66·3	1,177	1,105	50·8
1,600	1,142	6,341	170	1,118	5,200	139	1,139	4,815	140	1,159	3,725	120·0	1,147	2,281	81·4	1,122	1,571	63·2	1,141	1,038	47·8
1,800	1,125	6,154	165	1,101	5,040	135	1,122	4,670	136	1,138	3,590	115·3	1,121	2,178	77·7	1,097	1,502	60·4	1,108	979	45·0
2,000	1,109	5,971	160	1,085	4,890	131	1,106	4,540	132	1,118	3,470	111·2	1,097	2,086	74·4	1,074	1,440	57·9	1,078	927	42·6
2,200	1,093	5,799	155	1,069	4,750	127	1,090	4,410	129	1,099	3,350	107·5	1,075	2,003	71·5	1,052	1,381	55·5	1,053	884	40·7
2,400	1,077	5,630	150	1,055	4,630	124	1,075	4,285	125	1,082	3,245	104·2	1,055	1,930	68·0	1,032	1,329	53·4	1,030	846	39·0
2,600	1,061	5,474	146	1,041	4,510	120	1,061	4,175	122	1,066	3,150	101·1	1,037	1,864	66·5	1,014	1,283	51·6	1,009	812	37·8
2,800	1,046	5,322	142	1,028	4,400	117	1,048	4,075	119	1,052	3,070	98·5	1,020	1,804	64·4	996	1,233	49·8	990	782	36·0
3,000	1,032	5,169	138	1,016	4,300	115	1,036	3,980	116	1,038	2,990	95·9	1,004	1,747	62·4	980	1,190	48·2	973	755	34·7
3,200	1,018	5,030	134	1,004	4,200	112	1,024	3,890	113	1,025	2,915	93·5	990	1,699	60·6	965	1,162	46·7	958	732	33·7
3,400	1,004	4,892	131	993	4,100	110	1,012	3,800	111	1,013	2,845	91·3	978	1,658	59·2	952	1,131	45·5	945	712	32·8
3,600	990	4,766	127	984	4,030	108	1,002	3,725	109	1,002	2,785	89·4	966	1,618	57·7	940	1,103	44·3	934	696	32·0
3,800	978	4,642	124	976	3,960	106	994	3,665	107	992	2,730	87·6	955	1,581	56·4	930	1,080	43·4	924	681	31·3
4,000	966	4,529	121	968	3,900	104	986	3,605	105	982	2,675	85·8	945	1,548	55·2	920	1,050	42·5	916	[illegible]	[illegible]

…ir bursting Charges and Fu…ty.							Proof.			
Palliser, …ge Capacity.		…jectile.						Charge.		
…ight, …npty.	Bursting Charge.	Weight, empty.	Bur… in… Char…		Weight.	Feet per second.	No. of Rounds.	P.	R.L.G.	Projectile.
… ozs.	lbs. ozs.	lbs. ozs.	lbs. …		lbs. ozs.			lbs. ozs.	lbs. ozs.	lbs. ozs.
							1	110	- -	700 0
							2	115	- -	700 0
…0 0	18 0	- -	-	-	620 0	1,220				
…3 0	14 0	- -	-	-	600 0	1,180	2		87 8	600 0
				-	600 0	1,300				
				-	535 0	1,315	2		87 8	530 0
…3 2	6 14	- -	-	-	400 0	1,298	2		75 0	400 0
				-	400 0	1,364				
…4 8	5 8	- -	-	-	250 0	1,336	2		53 12	250 0
				-	250 0	1,420				
…5 8	4 8	- -	-	-	180 0	1,363	2		37 8	180 0
				-	180 0	1,413				
…2 8	2 8	- -	-	-	115 0	1,458	2		27 8	115 0
…2 8	2 8	- -	-	-	115 0	1,480	2		27 8	115 0
				-	115 0	1,525				
									17 8	115 0
									12 8	80 0
-	- -	- -	-	…ell -	64 0	1,170	2		10 0	64 0
-	- -	- -	-				2		10 0	64 0
-	- -	- -	-				2		10 0	64 0
							2	- -	3 12	16 0
-	- -	- -	-	…ell -	9 0	1,380	2	- -	2 3	9 0
-	- -	- -	-	-	9 0	1,234	2	- -	2 3	9 0
-	- -	- -	-				10	- -	0 8	7 0
-	- -	- -	-				10	- -		7 0
-	- -	- -	-	-	7 3	673	2	- -	0 10	7 0
-	- -	98 9½	3…	-	90 0	1,165	6	- -	18 0	110 0
-	- -	97 9½	3…	-	- -	- -				
-	- -	- -	-	…hell -	64 0	1,200	6	- -	13 0	64 0
-	- -	38 9½	0…	-	41 0	1,180	6	- -	7 8	40 0
-	- -	19 10	Gr… 7…	-	21 0	1,130	6	- -	3 12	20 0
-	- -	19 10	7…	-	21 0	1,000				
-	- -	10 6½	5…	…hell.	11 12	1,170	6	- -	2 0	12 0
-	- -	8 3¾	3…	-	9 4	1,057	6	- -	1 6	9 0
-	- -	5 7	2…				6	- -	1 2	6 0

… vertical fire with double sh…

Range Table for 12-inch Rifled M.L. Gun of 25 Tons.

Charge, 50 lbs. R.L.G. or 55 lbs. P. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Tenths of Fuze.
yds.	°	′	secs.		yds.	°	′	secs.	
100	0	12	0·28		2,100	4	43	5·94	*13*
160	—		—	*1*	2,200	4	57	6·25	
200	0	24	0·56		*2,255*	—		—	*14*
300	0	36	0·83		2,300	5	13	6·56	
325	—		—	*2*	2,400	5	29	6·87	
400	0	48	1·10		*2,410*	—		—	*15*
490	—		—	*3*	2,500	5	45	7·18	
500	1	0	1·37		*2,560*	—		—	*16*
600	1	13	1·64		2,600	6	1	7·50	
655	—		—	*4*	2,700	6	17	7·82	
700	1	26	1·91		*2,710*	—		—	*17*
800	1	39	2·18		2,800	6	33	8·14	
820	—		—	*5*	*2,860*	—		—	*18*
900	1	52	2·45		2,900	6	50	8·46	
985	—		—	*6*	3,000	7	7	8·78	
1,000	2	5	2·72		*3,005*	—		—	*19*
1,100	2	18	3·00		3,100	7	24	9·10	
1,150	—		—	*7*	*3,150*	—		—	*20*
1,200	2	32	3·28		3,200	7	41	9·43	
1,300	2	46	3·56		*3,295*	—		—	*21*
1,310	—		—	*8*	3,300	7	59	9·76	
1,400	3	0	3·85		3,400	8	17	10·09	
1,470	—		—	*9*	*3,440*	—		—	*22*
1,500	3	14	4·14		3,500	8	35	10·43	
1,600	3	28	4·43		*3,580*	—		—	*23*
1,630	—		—	*10*	3,600	8	54	10·77	
1,700	3	42	4·72		3,700	9	13	11·11	
1,790	—		—	*11*	*3,720*	—		—	*24*
1,800	3	57	5·02		3,800	9	32	11·45	
1,900	4	12	5·32		3,900	9	52	11·80	
1,945	—		—	*12*	4,000	10	12	12·16	
2,000	4	27	5·63						

Range Table for 12-inch Rifled M.L. Gun of 25 Tons.

Charge, battering, 67 lbs. R.L.G. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Tenths of Fuze.
yds.	°	′	secs.		yds.	°	′	secs.	
100	0	10	0·25		2,100	4	12	5·7	
140	—		—	*1*	*2,170*	—		—	*14*
200	0	21	0·5		2,200	4	26	6·0	
300	0	32	0·8		2,300	4	40	6·3	
310	—		—	*2*	*2,320*	—		—	*15*
400	0	43	1·0		2,400	4	54	6·6	
480	—		—	*3*	*2,470*	—		—	*16*
500	0	54	1·3		2,500	5	9	6·9	
600	1	5	1·5		2,600	5	24	7·2	
640	—		—	*4*	*2,620*	—		—	*17*
700	1	16	1·8		2,700	5	39	7·5	
800	1	27	2·1	*5*	*2,770*	—		—	*18*
900	1	39	2·3		2,800	5	54	7·8	
960	—		—	*6*	2,900	6	9	8·2	
1,000	1	51	2·6		*2,915*	—		—	*19*
1,100	2	3	2·9		3,000	6	24	8·5	
1,120	—		—	*7*	*3,060*	—		—	*20*
1,200	2	15	3·1		3,100	6	40	8·8	
1,270	—		—	*8*	3,200	6	56	9·1	
1,300	2	27	3·4		*3,205*	—		—	*21*
1,400	2	40	3·7		3,300	7	12	9·4	
1,420	—		—	*9*	*3,350*	—		—	*22*
1,500	2	53	4·0		3,400	7	28	9·7	
1,570	—		—	*10*	*3,495*	—		—	*23*
1,600	3	6	4·3		3,500	7	45	10·0	
1,700	3	19	4·5		3,600	8	1	10·3	
1,720	—		—	*11*	*3,640*	—		—	*24*
1,800	3	32	4·8		3,700	8	17	10·7	
1,870	—		—	*12*	3,800	8	34	11·0	
1,900	3	45	5·1		3,900	8	51	11·3	
2,000	3	58	5·4		4,000	9	9	11·7	
2,020	—		—	*13*					

Range Table for 12-inch Rifled M.L. Gun of 25 Tons.

Charge, battering, 85 lbs. P. powder.
Projectile, Palliser.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′			yds.	° ′		
100	0 7			2,500	4 58		
200	0 15			2,600	5 12		
300	0 23			2,700	5 26		
400	0 31			2,800	5 40		
500	0 39			2,900	5 54		
600	0 48			3,000	6 8		
700	0 58			3,100	6 22		
800	1 9			3,200	6 36		
900	1 20			3,300	6 50		
1,000	1 32			3,400	7 4		
1,100	1 44			3,500	7 19		
1,200	1 57			3,600	7 34		
1,300	2 10			3,700	7 49		
1,400	2 24			3,800	8 4		
1,500	2 38			3,900	8 19		
1,600	2 52			4,000	8 34		
1,700	3 6			4,100	8 49		
1,800	3 20			4,200	9 4		
1,900	3 34			4,300	9 19		
2,000	3 48			4,400	9 34		
2,100	4 2			4,500	9 49		
2,200	4 16			4,600	10 4		
2,300	4 30			4,700	10 19		
2,400	4 44			4,800	10 34		

Range Table for 12-inch Rifled M.L. Gun of 25 Tons.

Charge, battering, 85 lbs. P. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.	
100	0 5	0·23	
185	—	—	*1*
200	0 11	0·45	
300	0 18	0·67	
375	—	—	*2*
400	0 26	0·89	
500	0 35	1·11	
560	—	—	*3*
600	0 45	1·33	
700	0 56	1·56	
740	—	—	*4*
800	1 7	1·80	
900	1 18	2·04	
915	—	—	*5*
1,000	1 29	2·29	
1,085	—	—	*6*
1,100	1 40	2·54	
1,200	1 51	2·79	
1,255	—	—	*7*
1,300	2 2	3·04	
1,400	2 14	3·29	
1,425	—	—	*8*
1,500	2 26	3·55	
1,595	—	—	*9*
1,600	2 38	3·81	
1,700	2 50	4·07	
1,760	—	—	*10*
1,800	3 2	4·34	
1,900	3 14	4·61	
1,920	—	—	*11*
2,000	3 26	4·88	
2,080	—	—	*12*
2,100	3 38	5·15	
2,200	3 51	5·42	
2,240	—	—	*13*
2,300	4 4	5·69	
2,400	4 17	5·96	*14*
2,500	4 30	6·24	
2,560	—	—	*15*

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.	
2,600	4 43	6·52	
2,700	4 56	6·80	
2,715	—	—	*16*
2,800	5 9	7·08	
2,865	—	—	*17*
2,900	5 23	7·36	
3,000	5 37	7·65	
3,015	—	—	*18*
3,100	5 51	7·95	
3,160	—	—	*19*
3,200	6 5	8·25	
3,300	6 19	8·55	*20*
3,400	6 34	8·85	
3,440	—	—	*21*
3,500	6 49	9·16	
3,580	—	—	*22*
3,600	7 4	9·47	
3,700	7 19	9·48	
3,715	—	—	*23*
3,800	7 35	10·09	
3,850	—	—	*24*
3,900	7 52	10·40	
3,980	—	—	*25*
4,000	8 9	10·71	
4,100	8 26	11·03	
4,110	—	—	*26*
4,200	8 43	11·35	
4,235	—	—	*27*
4,300	9 0	11·67	
4,360	—	—	*28*
4,400	9 17	12·00	
4,480	—	—	*29*
4,500	9 34	12·33	
4,600	9 51	12·66	*30*
4,700	10 8	13·00	
4,720	—	—	*31*
4,800	10 25	13·34	
4,835	—	—	*32*

Range Table for 11-inch Rifled M.L. Gun of 25 Tons.

Charge, service, 60 lbs. P. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 13	0·28		2,600	6 19	7·56	
200	0 26	0·56		2,700	6 35	7·87	
300	0 39	0·84		2,800	6 51	8·18	
400	0 53	1·12		2,900	7 7	8·50	
500	1 7	1·40		3,000	7 23	8·82	
600	1 21	1·68		3,100	7 39	9·14	
700	1 35	1·96		3,200	7 56	9·46	
800	1 49	2·24		3,300	8 13	9·79	
900	2 3	2·53		3,400	8 30	10·12	
1,000	2 17	2·82		3,500	8 47	10·45	
1,100	2 31	3·11		3,600	9 4	10·78	
1,200	2 45	3·40		3,700	9 21	11·11	
1,300	3 0	3·69		3,800	9 38	11·44	
1,400	3 15	3·98		3,900	9 56	11·78	
1,500	3 30	4·27		4,000	10 14	12·12	
1,600	3 45	4·56		4,100	10 32	12·47	
1,700	4 0	4·85		4,200	10 50	12·82	
1,800	4 15	5·14		4,300	11 8	13·17	
1,900	4 30	5·43		4,400	11 26	13·53	
2,000	4 45	5·73		4,500	11 44	13·89	
2,100	5 0	6·03		4,600	12 2	14·25	
2,200	5 15	6·33		4,700	12 21	14·61	
2,300	5 31	6·63		4,800	12 40	14·97	
2,400	5 47	6·94		4,900	12 59	15·34	
2,500	6 3	7·25					

Range Table for 11-inch Rifled M.L. Gun of 25 Tons.

Charge, battering, 85 lbs. P. powder.
Projectile, Palliser shot and shell, and common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′			yds.	° ′		
100	0 12			2,500	4 43		
200	0 22			2,600	4 56		
300	0 32			2,700	5 10		
400	0 42			2,800	5 24		
500	0 52			2,900	5 38		
600	1 2			3,000	5 52		
700	1 12			3,100	6 6		
800	1 22			3,200	6 20		
900	1 32			3,300	6 34		
1,000	1 43			3,400	6 48		
1,100	1 54			3,500	7 3		
1,200	2 5			3,600	7 18		
1,300	2 16			3,700	7 33		
1,400	2 27			3,800	7 48		
1,500	2 38			3,900	8 3		
1,600	2 50			4,000	8 19		
1,700	3 2			4,100	8 35		
1,800	3 14			4,200	8 51		
1,900	3 26			4,300	9 7		
2,000	3 38			4,400	9 23		
2,100	3 51			4,500	9 40		
2,200	4 4			4,600	9 57		
2,300	4 17			4,700	10 14		
2,400	4 30			4,800	10 31		

Range Table for 10-inch Rifled M.L. Gun of 18 Tons.

Charge service, 40 lbs. R.L.G. or 44 lbs. P. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 13	0·26		2,200	5 13	6·56	
160	—	—	*1*	*2,205*	—	—	*15*
200	0 24	0·54		2,300	5 30	6·89	
300	0 36	0·82		*2,335*	—	—	*16*
320	—	—	*2*	2,400	5 47	7·22	
400	0 48	1·10		*2,465*	—	—	*17*
480	—	—	*3*	2,500	6 5	7·56	
500	1 1	1·38		*2,595*	—	—	*18*
600	1 14	1·67		2,600	6 23	7·90	
635	—	—	*4*	2,700	6 42	8·24	
700	1 27	1·86		*2,725*	—	—	*19*
785	—	—	*5*	2,800	7 1	8·58	
800	1 41	2·25		*2,850*	—	—	*20*
900	1 55	2·54		2,900	7 21	8·93	
930	—	—	*6*	*2,970*	—	—	*21*
1,000	2 9	2·83		3,000	7 41	9·29	
1,080	—	—	*7*	*3,090*	—	—	*22*
1,100	2 23	3·12		3,100	8 1	9·65	
1,200	2 37	3·42		3,200	8 21	10·02	
1,225	—	—	*8*	*3,210*	—	—	*23*
1,300	2 51	3·73		3,300	8 42	10·39	
1,370	—	—	*9*	*3,330*	—	—	*24*
1,400	3 6	4·04		3,400	9 3	10·76	
1,515	—	—	*10*	*3,445*	—	—	*25*
1,500	3 21	4·35		3,500	9 25	11·14	
1,600	3 36	4·66		*3,560*	—	—	*26*
1,655	—	—	*11*	3,600	9 47	11·52	
1,700	3 51	4·97		*3,675*	—	—	*27*
1,795	—	—	*12*	3,700	10 9	11·90	
1,800	4 7	5·28		*3,790*	—	—	*28*
1,900	4 23	5·60		3,800	10 32	12·29	
1,935	—	—	*13*	3,900	10 56	12·68	*29*
2,000	4 39	5·92		4,000	11 21	13·08	
2,070	—	—	*14*	*4,010*	—	—	*30*
2,100	4 56	6·24					

Range Table for 10-inch Rifled M.L. Gun of 18 Tons.

Charge, battering, 60 lbs. R.L.G. powder.

Projectile, Palliser.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′	secs.		yds.			
100	0 9	0·20		2,100			
200	0 18	0·43		2,200			
300	0 28	0·67		2,300			
400	0 38	0·91		2,400			
500	0 48	1·15		2,500			
600	0 58	1·40		2,600			
700	1 8	1·65		2,700			
800	1 18	1·91		2,800			
900	1 29	2·17		2,900			
1,000	1 40	2·43		3,000			
1,100	1 51	2·69		3,100			
1,200	2 2	2·96		3,200			
1,300	2 13	3·23		3,300			
1,400	2 25	3·50		3,400			
1,500	2 37	3·77		3,500			
1,600	2 49	4·05		3,600			
1,700	3 1	4·33		3,700			
1,800	3 13	4·61		3,800			
1,900	3 25	4·90		3,900			
2,000	3 38	5·19		4,000			

Range Table for 10-inch Rifled M.L. Gun of 18 Tons.

Charge, battering, 70 lbs. P. powder.
Projectile, Palliser.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′			yds.	° ′		
100	0 6			2,500	4 27		
200	0 13			2,600	4 40		
300	0 22			2,700	4 54		
400	0 31			2,800	5 8		
500	0 40			2,900	5 22		
600	0 49			3,000	5 36		
700	0 58			3,100	5 50		
800	1 7			3,200	6 4		
900	1 16			3,300	6 18		
1,000	1 26			3,400	6 32		
1,100	1 36			3,500	6 46		
1,200	1 47			3,600	7 0		
1,300	1 58			3,700	7 14		
1,400	2 9			3,800	7 28		
1,500	2 21			3,900	7 42		
1,600	2 33			4,000	7 56		
1,700	2 45			4,100	8 10		
1,800	2 57			4,200	8 24		
1,900	3 9			4,300	8 38		
2,000	3 22			4,400	8 52		
2,100	3 35			4,500	9 6		
2,200	3 48			4,600	9 20		
2,300	4 1			4,700	9 34		
2,400	4 14			4,800	9 48		

Range Table for 10-inch Rifled M.L. Gun of 18 Tons.

Charge, battering, 70 lbs. P. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 9	0·25		2,500	4 35	6·55	
170	—	—	*1*	*2,570*	—	—	*16*
200	0 18	0·50		2,600	4 48	6·85	
300	0 27	0·75		*2,715*	—	—	*17*
345	—	—	*2*	3,700	5 1	7·15	
400	0 36	1·00		2,800	5 15	7·45	
				2,855	—	—	*18*
500	0 46	1·25		2,900	5 29	7·75	
515	—	—	*3*	*2,995*	—	—	*19*
600	0 56	1·50					
685	—	—	*4*	3,000	5 43	8·05	
700	1 6	1·75		3,100	5 57	8·35	
800	1 16	2·00		*3,130*	—	—	*20*
855	—	—	*5*	3,200	6 12	8·66	
900	1 26	2·25		*3,265*	—	—	*21*
				3,300	6 27	8 98	
1,000	1 37	2·51		3,400	6 42	9·30	*22*
1,025	—	—	*6*				
1,100	1 48	2·77		3,500	6 57	9·62	
1,195	—	—	*7*	*3,530*	—	—	*23*
1,200	1 59	3·03		3,600	7 12	9·94	
1,300	2 10	3·29		*3,660*	—	—	*24*
1,355	—	—	*8*	3,700	7 28	10·27	
1,400	2 21	3·55		*3,785*	—	—	*25*
				3,800	7 44	10·60	
1,500	2 32	3·81		3,900	8 0	10·94	
1,515	—	—	*9*	*3,910*	—	—	*26*
1,600	2 44	4·07					
1,675	—	—	*10*	4,000	8 16	11·29	
1,700	2 56	4·33		*4,030*	—	—	*27*
1,800	3 8	4·60		4,100	8 32	11·64	
1,825	—	—	*11*	*4,150*	—	—	*28*
1,900	3 20	4·87		4,200	8 48	11·99	
1,975	—	—	*12*	*4,270*	—	—	*29*
				4,300	9 5	12·35	
2,000	3 32	5·15		*4,385*	—	—	*30*
2,100	3 44	5·43		4,400	9 22	12·71	
2,125	—	—	*13*				
2,200	3 56	5·71		4,500	9 39	13·07	*31*
2,275	—	—	*14*	4,600	9 57	13·44	
2,300	4 9	5·99		*4,615*	—	—	*32*
2,400	4 22	6·27		4,700	10 15	13·81	
2,425	—	—	*15*	*4,725*	—	—	*33*
				4,800	10 33	14·18	
				4,835	—	—	*34*

Range Table for 9-inch Rifled M.L. Gun of 12 Tons.

Charge, 30 lbs. R.L.G. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 11	0·30		2,200	5 0	6·07	
165	—	—	*1*	*2,290*	—	—	*14*
200	0 23	0·57		2,300	5 15	6·37	
300	0 35	0·84		2,400	5 30	6·68	
335	—	—	*2*	*2,435*	—	—	*15*
400	0 47	1·11		2,500	5 45	6·99	
500	1 0	1·38	*3*	*2,580*	—	—	*16*
600	1 13	1·65		2,600	6 0	7·30	
670	—	—	*4*	2,700	6 15	7·62	
700	1 26	1·92		*2,720*	—	—	*17*
800	1 39	2·19		2,800	6 30	7·94	
835	—	—	*5*	*2,860*	—	—	*18*
900	1 52	2·46		2,900	6 46	8·26	
1,000	2 6	2·73	*6*	3,000	7 2	8·58	*19*
1,100	2 20	3·00		3,100	7 18	8·90	
1,170	—	—	*7*	*3,140*	—	—	*20*
1,200	2 34	3·27		3,200	7 34	9·23*	
1,300	2 48	3·54		*3,280*	—	—	*21*
1,335	—	—	*8*	3,300	7 51	9·56	
1,400	3 2	3·81		3,400	8 8	9·90	
1,500	3 16	4·08		*3,410*	—	—	*22*
1,505	—	—	*9*	3,500	8 25	10·24	
1,600	3 30	4·35		*3,540*	—	—	*23*
1,665	—	—	*10*	3,600	8 42	10·58	
1,700	3 45	4·63		*3,675*	—	—	*24*
1,800	4 0	4·91		3,700	8 59	10·92	
1,825	—	—	*11*	3,800	9 16	11·26	
1,900	4 15	5·20		*3,805*	—	—	*25*
1,980	—	—	*12*	3,900	9 34	11·63	
2,000	4 30	5·49		*3,930*	—	—	*26*
2,100	4 45	5·78		4,000	9 52	12·01	
2,135	—	—	*13*	*4,045*	—	—	*27*

* Limits of present fuze.

Range Table for 9-inch Rifled M.L. Gun of 12 Tons.

Charge, battering, 43 lbs. R.L.G. powder.
Projectile, Palliser or Common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 9	0·22		2,000	3 41	5·22	
200	0 18	0·45		*2,035*	—	—	*11*
205	—	—	*1*	2,100	3 55	5·51	
300	0 28	0·68		2,200	4 9	5·81	*12*
400	0 38	0·92		2,300	4 24	6·11	
410	—	—	*2*	*2,370*	—	—	*13*
500	0 48	1·16		2,400	4 39	6·41	
600	0 58	1·40		2,500	4 55	6·72	
620	—	—	*3*	*2,530*	—	—	*14*
700	1 8	1·65		2,600	5 11	7·03	
800	1 18	1·90		*2,685*	—	—	*15*
820	—	—	*4*	2,700	5 27	7·35	
900	1 28	2·16		2,800	5 43	7·67	
1,000	1 39	2·43		*2,835*	—	—	*16*
1,005	—	—	*5*	2,900	5 59	7·99	
1,100	1 50	2·70		*2,990*	—	—	*17*
1,185	—	—	*6*	3,000	6 15	8·31	
1,200	2 1	2·97		3,100	6 31	8·63	
1,300	2 12	3·24		*3,140*	—	—	*18*
1,360	—	—	*7*	3,200	6 47	8·95	
1,400	2 23	3·52		*3,290*	—	—	*19*
1,500	2 35	3·80		3,300	7 3	9·28	
1,530	—	—	*8*	3,400	7 19	9·61	
1,600	2 48	4·08		*3,435*	—	—	*20*
1,700	3 1	4·36		3,500	7 35	9·94	
1,790	—	—	*9*	3,600	7 52	10·27	
1,800	3 14	4·64		3,700	8 9	10·61	
1,870	—	—	*10*	3,800	8 26	10·95	
1,900	3 27	4·93		3,900	8 43	11·31	
				4,000	9 0	11·67	

Range Table for 9-inch Rifled M.L. Gun of 12 Tons.

Charge, battering, 50 lbs. P. powder.

Projectile, Palliser or common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 6	0·23		2,600	4 39	6·90	
185	—	—	*1*	2,700	4 53	7·22	
200	0 13	0·46		*2,705*	—	—	*16*
300	0 21	0·69		2,800	5 8	7·54	
370	—	—	*2*	*2,840*	—	—	*17*
400	0 29	0·92		2,900	5 23	7·86	
				2,970	—	—	*18*
500	0 37	1·15					
550	—	—	*3*	3,000	5 38	8·18	
600	0 46	1·39		3,100	5 53	8·50	*19*
700	0 55	1·63		3,200	6 8	8·82	
730	—	—	*4*	*3,230*	—	—	*20*
800	1 4	1·87		3,300	6 23	9·15	
900	1 13	2·11		*3,360*	—	—	*21*
910	—	—	*5*	3,400	6 39	9·48	
				3,490	—	—	*22*
1,000	1 23	2·36					
1,090	—	—	*6*	3,500	6 55	9·81	
1,200	1 33	2·61		3,600	7 11	10·14	
1,200	1 44	2·87		*3,620*	—	—	*23*
1,270	—	—	*7*	3,700	7 27	10·47	
1,300	1 55	3·13		*3,750*	—	—	*24*
1,400	2 6	3·40		3,800	7 43	10·81	
1,440	—	—	*8*	*3,880*	—	—	*25*
				3,900	8 0	11·15	
1,500	2 17	3·67					
1,600	2 28	3·95		4,000	8 17	11·50	
1,610	—	—	*9*	*4,010*	—	—	*26*
1,700	2 40	4·23		4,100	8 34	11·85	
1,780	—	—	*10*	*4,140*	—	—	*27*
1,800	2 52	4·51		4,200	8 51	12·20	
1,900	3 4	4·80		*4,265*	—	—	*28*
1,945	—	—	*11*	4,300	9 9	12·55	
				4,390	—	—	*29*
2,000	3 17	5·09		4,400	9 27	12·91	
2,100	3 30	5·38	*12*				
2,200	3 43	5·68		4,500	9 45	13·27	
2,260	—	—	*13*	*4,515*	—	—	*30*
2,800	3 57	5·98		4,600	10 3	13·63	
2,400	4 11	6·28		*4,640*	—	—	*31*
2,410	—	—	*14*	4,700	10 21	13·99	
				4,765	—	--	*32*
2,500	4 25	6·59		4,800	10 39	14·36	
2,560	—	—	*15*				

Range Table for 8-inch Rifled M.L. Gun of 9 Tons.

Charge, 20 lbs. R.L.G. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 10	0·27		2,200	4 58	6·64	
170	—	—	*1*	*2,255*	—	—	*15*
200	0 21	0·55		2,300	5 15	6·98	
300	0 33	0·84		*2,385*	—	—	*16*
330	—	—	*2*	2,400	5 32	7·32	
400	0 45	1·13		2,500	5 49	7·66	
485	—	—	*3*	*2,520*	—	—	*17*
500	0 57	1·42		2,600	6 7	8·00	
600	1 9	1·71		*2,655*	—	—	*18*
640	—	—	*4*	2,700	6 25	8·35	
700	1 21	2·01		*2,780*	—	—	*19*
795	—	—	*5*	2,800	6 43	8·70	
800	1 33	2·31		2,900	7 2	9·05	
900	1 46	2·61		*2,910*	—	—	*20*
945	—	—	*6*	3,000	7 21	9·41	
1,000	1 59	2·91		*3,035*	—	—	*21*
1,095	—	—	*7*	3,100	7 40	9·78	
1,100	2 12	3·21		*3,160*	—	—	*22*
1,200	2 26	3·51		3,200	7 59	10·15	
1,245	—	—	*8*	*3,280*	—	—	*23*
1,300	2 40	3·81		3,300	8 19	10·53	
1,395	—	—	*9*	*3,395*	—	—	*24*
1,400	2 54	4·11		3,400	8 39	10·92	
1,500	3 8	4·41		3,500	8 59	11·31	
1,550	—	—	*10*	*3,515*	—	—	*25*
1,600	3 23	4·72		3,600	9 19	11·70	
1,695	—	—	*11*	*3,630*	—	—	*26*
1,700	3 38	5·03		3,700	9 39	12·09	
1,800	3 54	5·35		*3,745*	—	—	*27*
1,835	—	—	*12*	3,800	9 59	12·48	
1,900	4 10	5·67		*3,860*	—	—	*28*
1,975	—	—	*13*	3,900	10 20	12·88	
2,000	4 26	5·99		*3,975*	—	—	*29*
2,100	4 42	6·31		4,000	10 42	13·26	
2,115	—	—	*14*	*4,085*	—	—	*30*

Range Table for 8-inch Rifled M.L. Gun of 9 Tons.

Charge, battering, 30 lbs. R.L.G. powder.

Projectile, Palliser or common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.			
100	0 9	0·25		2,100			
200	0 18	0·51		2,200			
300	0 27	0·77		2,300			
400	0 36	1·03		2,400			
500	0 45	1·30		2,500			
600	0 55	1·57		2,600			
700	1 5	1·84		2,700			
800	1 15	2·11		2,800			
900	1 26	2·39		2,900			
1,000	1 37	2·67		3,000			
1,100	1 48	2·95		3,100			
1,200	1 59	3·23		3,200			
1,300	2 10	3·51		3,300			
1,400	2 21	3·79		3,400			
1,500	2 33	4·07		3,500			
1,600	2 45	4·35		3,600			
1,700	2 57	4·63		3,700			
1,800	3 9	4·91		3,800			
1,900	3 21	5·21		3,900			
2,000	3 33	5·52		4,000			

Range Table for 8-inch Rifled M.L. Gun of 9 Tons.

Charge, battering, 35 lbs. P. powder.
Projectile, Palliser or common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 6	0·23		2,600	4 52	7·07	
180	—	—	*1*	*2,610*	—	—	*16*
200	0 13	0·46		2,700	5 7	7·38	
300	0 22	0·69		*2,745*	—	—	*17*
360	—	—	*2*	2,800	5 22	7·69	
400	0 31	0·92		*2,875*	—	—	*18*
				2,900	5 38	8·00	
500	0 40	1·16					
540	—	—	*3*	3,000	5 54	8·32	
600	0 49	1·40		*3,005*	—	—	*19*
700	0 59	1·65		3,100	6 10	8·64	
715	—	—	*4*	*3,135*	—	—	*20*
800	1 9	1·90		3,200	6 26	8·97	
885	—	—	*5*	*3,265*	—	—	*21*
900	1 19	2·15		3,300	6 42	9·30	
				3,395	—	—	*22*
1,000	1 29	2·41		3,400	6 58	9·63	
1,055	—	—	*6*				
1,100	1 39	2·67		3,500	7 14	9·96	
1,200	1 50	2·94		*3,525*	—	—	*23*
1,225	—	—	*7*	3,600	7 30	10·29	
1,300	2 1	3·21		*3,655*	—	—	*24*
1,395	—	—	*8*	3,700	7 46	10·62	
1,400	2 12	3·49		*3,785*	—	—	*25*
				3,800	8 2	10·95	
1,500	2 23	3·77		3,900	8 18	11·29	
1,555	—	—	*9*	*3,915*	—	—	*26*
1,600	2 34	4·05					
1,700	2 46	4·34		4,000	8 34	11·63	
1,715	—	—	*10*	*4,045*	—	—	*27*
1,800	2 59	4·63		4,100	8 51	11·98	
1,875	—	—	*11*	*4,170*	—	—	*28*
1,900	3 12	4·92		4,200	9 8	12·33	
				4,295	—	—	*29*
2,000	3 26	5·22		4,300	9 25	12·68	
2,030	—	—	*12*	4,400	9 42	13·04	
2,100	3 40	5·52		*4,420*	—	—	*30*
2,180	—	—	*13*				
2,200	3 54	5·83		4,500	9 59	13·40	
2,300	4 8	6·14		*4,545*	—	—	*31*
2,330	—	—	*14*	4,600	10 17	13·76	
2,400	4 22	6·45		*4,665*	—	—	*32*
2,470	—	—	*15*	4,700	10 35	14·13	
				4,785	—	—	*33*
2,500	4 37	6·76		4,800	10 53	14·50	

Range Table for 7-inch Rifled M.L. Gun of 7 Tons.

Charge, 14 lbs. R.L.G. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′	secs.	ins.	yds.	° ′	secs.	ins.
100	0 11	0·28	0·05	2,500	5 46	7·32	1·70
200	0 21	0·56	0·15	2,600	6 3	7·64	1·75
300	0 32	0·84	0·20	2,700	6 20	7·96	1·85
400	0 43	1·12	0·25	2,800	6 38	8·28	1·90
500	0 54	1·40	0·30	2,900	6 56	8·60	2·00
600	1 5	1·68	0·40	3,000	7 14	8·93	
700	1 16	1·96	0·45	3,100	7 32	9·26	
800	1 28	2·24	0·50	3,200	7 50	9·59	
900	1 40	2·52	0·60	3,300	8 8	9·93	
1,000	1 53	2·80	0·65	3,400	8 26	10·27	
1,100	2 6	3·08	0·70	3,500	8 44		
1,200	2 20	3·37	3·80	3,600	9 2		
1,300	2 34	3·60	0·85	3,700	9 20		
1,400	2 49	3·95	0·90	3,800	9 38		
1,500	3 4	4·24	1·00	3,900	9 57		
1,600	3 20	4·53	1·05	4,000	10 16		
1,700	3 36	4·83	1·10	4,100	10 35		
1,800	3 52	5·13	1·20	4,200	10 54		
1,900	4 8	5·44	1·25	4,300	11 14		
2,000	4 24	5·75	1·30	4,400	11 34		
2,100	4 40	6·06	1·40	4,500	11 54		
2,200	4 56	6·37	1·45	4,600	12 15		
2,300	5 12	6·68	1·55	4,700	12 36		
2,400	5 29	7·00	1·60	4,800	12 57		

Range Table for 7-inch Rifled M.L. Gun of 7 Tons.

Charge, 22 lbs. R.L.G. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′	secs.	ins.	yds.	° ′	secs.	ins.
100	0 5	0·25	0·05	2,500	4 16	6·50	1·55
200	0 11	0·47	0·10	2,600	4 30	6·81	1·65
300	3 18	0·69	0·15	2,700	4 45	7·13	1·70
400	0 25	0·91	0·20	2,800	5 0	7·45	1·80
500	0 33	1·14	0·25	2,900	5 15	7·77	1·85
600	0 41	1·37	0·35	3,000	5 30	8·09	1·95
700	0 49	1·60	0·40	3,100	5 45	8·41	2·00
800	0 58	1·84	0·45	3,200	6 0	8·73	
900	1 7	2·08	0·50	3,300	6 15	9·05	
1,000	1 16	2·32	0·55	3,400	6 30	2·37	
1,100	1 26	2·57	0·60	3,500	6 46	0·69	
1,200	1 36	2·82	0·70	3,600	7 2		
1,300	1 46	3·08	0·75	3,700	7 18		
1,400	1 57	3·34	0·80	3,800	7 35		
1,500	2 8	3·60	0·85	3,900	7 52		
1,600	2 19	3·87	0·95	4,000	8 9		
1,700	2 30	4·14	1·00	4,100	8 27		
1,800	2 42	4·42	1·05	4,200	8 45		
1,900	2 55	4·70	1·15	4,300	9 3		
2,000	3 8	4·99	1·20	4,400	9 22		
2,100	3 21	5·28	1·25	4,500	9 41		
2,200	3 34	5·58	1·35	4,600	10 0		
2,300	3 48	5·88	1·40	4,700	10 20		
2,400	4 2	6·19	1·50	4,800	10 40		

Range Table for 7-inch Rifled M.L. Gun of 6½ Tons.

Charge, 14 lbs. R.L.G. powder.
Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.
yds.	°	′		ins.	yds.	°	′		ins.
100	0	10		0·05	2,100	4	43		1·45
200	0	21		0·15	2,200	5	0		1·50
300	0	31		0·20	2,300	5	18		1·60
400	0	42		0·25	2,400	5	36		1·65
500	0	54		0·30	2,500	5	54		1·75
600	1	6		0·40	2,600	6	12		1·85
700	1	18		0·45	2,700	6	31		1·90
800	1	31		0·50	2,800	6	50		2·00
900	1	44		0·60	2,900	7	9		
1,000	1	57		0·65	3,000	7	29		
1,100	2	10		0·70	3,100	7	48		
1,200	2	24		0·80	3,200	8	8		
1,300	2	38		0·85	3,300	8	28		
1,400	2	52		0·95	3,400	8	48		
1,500	3	7		1·00	3,500	9	8		
1,600	3	22		1·05	3,600	9	29		
1,700	3	37		1·15	3,700	9	49		
1,800	3	53		1·20	3,800	10	10		
1,900	4	9		1·30	3,900	10	31		
2,000	4	26		1·35	4,000	10	52		

Range Table for 7-inch Rifled M.L. Gun of 6½ Tons.

Charge, 14 lbs. R.L.G. powder.

Projectile, double shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.*	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′	secs.	ins.	yds.			
100	0 14	0·80		1,700			
155	—	—	*1*	1,800			
200	0 28	0·60		1,900			
300	0 42	0·90		2,000			
315	—	—	*2*	2,100			
400	0 56	1·20		2,200			
470	—	—	*3*	2,300			
500	1 10	1·50		2,400			
600	1 25	1·80		2,500			
630	—	—	*4*	2,600			
700	1 41	2·15		2,700			
785	—	—	*5*	2,800			
800	1 57	2·45		2,900			
900	2 14	2·75		3,000			
940	—	—	*6*	3,100			
1,000	2 31	3·10		3,200			
1,080	—	—	*7*	3,300			
1,100	2 50	3·40		3,400			
1,200	3 9	3·75		3,500			
1,235	—	—	*8*	3,600			
1,300				3,700			
1,400				3,800			
1,500				3,900			
1,600				4,000			

* These lengths of fuzes apply equally to the L.S. 7-inch gun of 7 tons when firing double shell. Charge, 14 lbs.

Range Table for 7-inch Rifled M.L. Gun of 6½ Tons.

Charge, battering, 22 lbs. R.L.G. powder.

Projectile, Palliser or common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.							
Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.*	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.*
yds.	° ′		ins.	yds.	° ′		ins.
100	0 6		0·05	2,400	4 18		1·55
200	0 13		0·10	2,500	4 33		1·60
300	0 21		0·15	2,600	4 48		1·70
400	0 30		0·25	2,700	5 3		1·75
500	0 38		0·30	2,800	5 19		1·85
600	0 47		0·35	2,900	5 35		1·95
700	0 56		0·40	3,000	5 51		2·05
800	1 5		0·45	3,100	6 7		
900	1 14		0·55	3,200	6 24		
1,000	1 24		0·60	3,300	6 41		
1,100	1 34		0·65	3,400	6 58		
1,200	1 45		0·75	3,500	7 15		
1,300	1 56		0·80	3,600	7 32		
1,400	2 7		0·85	3,700	7 49		
1,500	2 19		0·90	3,800	8 6		
1,600	2 31		1·00	3,900	8 24		
1,700	2 43		1·05	4,000	8 42		
1,800	2 56		1·10	4,100	9 0		
1,900	3 9		1·15	4,200	9 18		
2,000	3 22		1·25	4,300	9 36		
2,100	3 35		1·30	4,400	9 55		
2,200	3 49		1·40	4,500	10 14		
2,300	4 3		1·50	4,600	10 34		

* Boxer's 2-inch wood time fuze for rifled M.L. and smooth-bore guns.

Range Table for 7-inch Rifled M.L. Gun of 6½ Tons.

Charge, battering, 30 lbs. P. powder.

Projectile, Palliser or common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 4	0·20		2,500	3 49	6·23	
190	—	—	*1*	2,600	4 2	6·52	
200	0 10	0·42		*2,605*	—	—	*16*
300	0 16	0·64		2,700	4 15	6·81	
380	—	—	*2*	*2,745*	—	—	*17*
400	0 23	0·86		2,800	4 28	7·11	
				2,880	—	—	*18*
500	0 30	1·08		2,900	4 41	7·41	
565	—	—	*3*				
600	0 37	1·30		3,000	4 54	7·72	
700	0 44	1·53		*3,015*	—	—	*19*
745	—	—	*4*	3,100	5 8	8·03	
800	0 51	1·76		*3,150*	—	—	*20*
900	0 59	1·99		3,200	5 23	8·34	
920	—	—	*5*	*3,280*	—	—	*21*
				3,300	5 38	8·66	
1,000	1 7	2·23		3,400	5 53	8·98	
1,090	—	—	*6*	*3,410*	—	—	*22*
1,100	1 16	2·47					
1,200	1 25	2·72		3,500	6 9	9·30	
1,260	—	—	*7*	*3,535*	—	—	*23*
1,300	1 35	2·97		3,600	6 24	9·62	
1,400	1 45	3·22		*3,660*	—	—	*24*
1,420	—	—	*8*	3,700	6 40	9·94	
				3,785	—	—	*25*
1,500	1 55	3·47		3,800	6 56	10·26	
1,580	—	—	*9*	3,900	7 13	10·59	
1,600	2 5	3·73		*3,905*	—	—	*26*
1,700	2 15	4·00					
1,735	—	—	*10*	4,000	7 30	10·93	
1,800	2 26	4·27		*4,025*	—	—	*27*
1,885	—	—	*11*	4,100	7 47	11·28	
1,900	2 37	4·54		4,200	8 4	11·63	
				4,300	8 21	11·98	
2,000	2 48	4·82		4,400	8 39	12·34	
2,035	—	—	*12*				
2,100	3 0	5·10		4,500	8 57	12·70	
2,180	—	—	*13*	4,600	9 15	13·07	
2,200	3 12	5·38		4,700	9 33	13·45	
2,300	3 24	5·66		4,800	9 51	13·83	
2,325	—	—	*14*				
2,400	3 36	5·94					
2,465	—	—	*15*				

Range Table for 7-inch Rifled B.L. Gun of 82 Cwt.

Charge, 11 lbs. R.L.G. powder.

Projectile, common shell of 90 lbs.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.
yds.	°	′	secs.	ins.	yds.	°	′	secs.	ins.
100	0	9	0·26	0·05	2,100	5	27	6·62	1·35
200	0	21	0·56	0·10	2,200	5	47	6·97	1·40
300	0	33	0·86	0·15	2,300	6	7	7·30	1·50
400	0	45	1·16	0·20	2,400	6	27	7·65	1·55
500	0	58	1·46	0·30	2,500	6	47	7·97	1·65
600	1	11	1·77	0·35	2,600	7	7	8·31	1·70
700	1	25	2·08	0·45	2,700	7	27	8·65	1·75
800	1	40	2·39	0·50	2,800	7	47	9·00	1·85
900	1	55	2·71	0·55	2,900	8	7	9·36	1·90
1,000	2	10	3·03	0·60	3,000	8	27	9·71	2·00
1,100	2	26	3·34	0·70	3,100	8	47	10·06	
1,200	2	43	3·66	0·75	3,200	9	7	10·42	
1,300	3	0	4·00	0·80	3,300	9	27	10·80	
1,400	3	17	4·30	0·90	3,400	9	47	11·17	
1,500	3	34	4·61	0·95	3,500	10	7	11·63	
1,600	3	52	4·95	1·00	3,600	10	27	12·00	
1,700	4	11	5·29	1·10	3,700				
1,800	4	30	5·61	1·15	3,800				
1,900	4	49	5·95	1·20	3,900				
2,000	5	8	6·29	1·30	4,000				

Range Table for 80-pr. Converted Rifled M.L. Gun of 5 Tons.

Charge, 10 lbs. R.L.G.

Projectile, common shell 80 lbs.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								—			
Distance of Object.	Eleva-tion.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Eleva-tion.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Corre-spond-ing Range.	Tenths of Fuze.	Corre-spond-ing Range.
yds.	° ′	secs.	ins.	yds.	° ′	secs.	ins.		yds.		yds.
100	0 11	0·28	0·05	2,100	4 52	6·32	1·35	1	260	12	2,470
200	0 23	0·57	0·15	2,200	5 9	6·05	1·45	1·5	390	13	2,630
300	0 35	0·86	0·20	2,300	5 27	6·98	1·50	2	520	14	2,775
400	0 47	1·15	0.25	2,400	5 46	7·32	1·55	2·5	630	15	2,915
500	0 59	1·44	0·30	2,500	6 5	7·66	1·65	3	750	16	3,055
600	1 12	1·73	0·40	2,600	6 25	8·00	1·75	3·5	860	17	3,190
700	1 25	2·02	0·45	2,700	6 45	8·35	1·80	4	980	18	3,320
800	1 38	2·31	0·50	2,800	7 6	8·70	1·90	4·5	1,080	19	3,445
900	1 51	2·61	0·55	2,900	7 27	9·05	1·95	5	1,190	20	3,570
1,000	2 4	2·91	0·65	3,000	7 49	9·41	2·05	5·5	1,290		
1,100	2 18	3·21	0·70	3,100	8 11	9·77	2·10	6	1,400		
1,200	2 32	3·51	0·75	3,200	8 34	10·13	2·20	6·5	1,495		
1,300	2 46	3·82	0·80	3,300	8 57	10·50	2·30	7	1,595		
1,400	3 0	4·13	0·90	3,400	9 20	10·87	2·35	7·5	1,695		
1,500	3 15	4·44	0·95	3,500	9 44	11·25	2·45	8	1,785		
1,600	3 30	4·75	1·00					8·5	1,880		
1,700	3 46	5·06	1·10					9	1,970		
1,800	4 2	5·37	1·15					9·5	2,060		
1,900	4 18	5·68	1·20					10	2,145		
2,000	4 35	6·00	1·30					11	2,235		

Range Table for 64-pr. Rifled M.L. Gun of 64 Cwt., and 64-pr. Converted Guns of 71 and 58 Cwt.

Charge, 8 lbs. R.L.G. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.
yds.	°	′	secs.	ins.	yds.	°	′	secs.	ins.
100	0	10	0·25	0·05	2,100	4	48	6·16	1·40
200	0	21	0·50	0·10	2,200	5	6	6·51	1·50
300	0	32	0·75	0·15	2,300	5	25	6·87	1·60
400	0	43	1·02	0·25	2,400	5	44	7·23	1·65
500	0	55	1·29	0·30	2,500	6	4	7·59	1·75
600	1	7	1·57	0·35	2,600	6	24	7·96	1·85
700	1	19	1·86	0·45	2,700	6	45	8·32	1·90
800	1	32	2·15	0·50	2,800	7	6	8·70	2·00
900	1	45	2·42	0·55	2,900	7	28	9·09	
1,000	1	58	2·72	0·60	3,000	7	50	9·47	
1,100	2	12	2·99	0·70	3,100	8	13	9·87	
1,200	2	26	3·29	0·75	3,200	8	36	10·27	
1,300	2	40	3·58	0·80	3,300	9	0	10·68	
1,400	2	55	3·89	0·90	3,400	9	24	11·09	
1,500	3	10	4·20	0·95	3,500	9	49	11·51	
1,600	3	25	4·51	1·05	3,600	10	14	11·93	
1,700	3	41	4·81	1·10	3,700				
1,800	3	57	5·15	1·20	3,800				
1,900	4	14	5·48	1·25	3,900				
2,000	4	31	5·82	1·35	4,000				

Range Table for 64-pr. Rifled B.L. Gun of 61 Cwt.

Charge, 9 lbs. R.L.G. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.
yds.	°	′	secs.	ins.	yds.	°	′	secs.	ins.
100	0	10	0·28	0·05	2,100	5	2	6·49	1·35
200	0	20	0·56	0·10	2,200	5	20	6·84	1·40
300	0	30	0·84	0·20	2,300	5	38	7·19	1·50
400	0	42	1·12	0·25	2,400	5	58	7·54	1·55
500	0	54	1·41	0·30	2,500	6	18	7·90	1·60
600	1	6	1·70	0·35	2,600	6	38	8·26	1·70
700	1	18	1·99	0·40	2,700	6	58	8·62	1·75
800	1	32	2·29	0·50	2,800	7	18	8·98	1·85
900	1	46	2·59	0·55	2,900	7	38	9·34	1·90
1,000	2	0	2·89	0·60	3,000	7	58	9·71	1·95
1,100	2	14	3·19	0·65	3,100	8	18	10·08	2·05
1,200	2	30	3·50	0·75	3,200	8	40	10·46	
1,300	2	46	3·82	0·80	3,300	9	2	10·84	
1,400	3	2	4·15	0·85	3,400	9	24	11·23	
1,500	3	18	4·48	0·95	3,500	9	46	11·63	
1,600	3	34	4·81	1·00	3,600	10	8	12·03	
1,700	3	50	5·14	1·05	3,700	10	30	12·44	
1,800	4	8	5·47	1·15	3,800	10	52	12·86	
1,900	4	26	5·80	1·20	3,900	11	14	13·28	
2,000	4	44	6·14	1·25	4,000	11	36	13·71	

Range Table for 40-pr. Rifled B.L. Gun of 32 Cwt.

Charge, 5 lbs. R.L.G. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.
yds.	°	′	secs.	ins.	yds.	°	′	secs.	ins.
100	0	10	0·35	0·05	2,100	5	27	6·60	1·35
200	0	21	0·65	0·10	2,200	5	45	7·00	1·40
300	0	33	0·95	0·15	2,300	6	4	7·35	1·45
400	0	45	1·25	0·20	2,400	6	24	7·70	1·55
500	0	58	1·55	0·25	2,500	6	44	8·05	1·60
600	1	12	1·85	0·35	2,600	7	5	8·45	1·70
700	1	27	2·15	0·40	2,700	7	27	8·80	1·75
800	1	42	2·45	0·50	2,800	7	49	9·20	1·85
900	1	57	2·75	0·55	2,900				
1,000	2	13	3·05	0·60	3,000				
1,100	2	29	3·35	0·65	3,100				
1,200	2	46	3·70	0·75	3,200				
1,300	3	3	4·00	0·80	3,300				
1,400	3	21	4·30	0·85	3,400				
1,500	3	39	4·65	0·95	3,500				
1,600	3	57	4·95	1·00	3,600				
1,700	4	15	5·30	1·05	3,700				
1,800	4	33	5·60	1·10	3,800				
1,900	4	51	5·95	1·20	3,900				
2,000	5	9	6·30	1·25	4,000				

Range Table for 20-pr. Rifled B.L. Gun of 16 Cwt.

Charge, 2 lbs. 8 ozs. R.L.G. powder.

Projectile, shot or shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.		Time of Flight.	Lengths of Fuze.
yds.	°	′	secs.	ins.	yds.	°	′	secs.	ins.
100	0	11	0·30	0·15	2,100	5	58	7·10	3·80
200	0	25	0·60	0·30	2,200	6	19	7·50	4·00
300	0	39	0·90	0·50	2,300	6	40	7·85	
400	0	53	1·25	0·65	2,400	7	1	8·20	
500	1	8	1·60	0·85	2,500	7	22	8·60	
600	1	23	1·90	1·00	2,600	7	43	8·95	
700	1	38	2·25	1·20	2,700	8	4	9·30	
800	1	53	2·60	1·35	2,800	8	25	9·70	
900	2	9	2·90	1·55	2,900	8	46	10·05	
1,000	2	26	3·25	1·75	3,000	9	7	10·40	
1,100	2	44	3·60	1·90	3,100	9	28	10·80	
1,200	3	3	3·95	2·10	3,200	9	49	11·20	
1,300	3	22	4·30	2·30	3,300	10	10	11·55	
1,400	3	41	4·65	2·50	3,400	10	32	11·90	
1,500	4	0	5·00	2·70	3,500	10	54	12·35	
1,600	4	19	5·35	2·85	3,600				
1,700	4	38	5·70	3·05	3,700				
1,800	4	57	6·00	3·25	3,800				
1,900	5	16	6·35	3·45	3,900				
2,000	5	37	6·70	3·65	4,000				

Range Table for 16-pr. R.M.L. Gun of 12 Cwt.

Charge, 3 lbs.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								—			
Distance of Object.	Eleva-tion.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Eleva-tion.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Range.	Tenths of Fuze.	Range.
yds.	° ′	secs.	ins.	yds.	° ′	secs.	ins.		yds.		yds.
100	0 0	0·25	0·05	2,100	4 33	6·25	1·25	1	200	11	1,875
200	0 0	0·50	0·10	2,200	4 51	6·60	1·30	1·5	295	12	2,020
300	0 7	0·76	0·15	2,300	5 10	6·96	1·40	2	390	13	2,165
400	0 19	1·03	0·20	2,400	5 30	7·32	1·45	2·5	485	14	2,305
500	0 31	1·30	0·25	2,500	5 50	7·69	1·55	3	575	15	2,445
600	0 44	1·58	0·30	2,600	6 10	8·06	1·60	3·5	665	16	2,580
700	0 57	1·83	0·35	2,700	6 30	8·44	1·70	4	755	17	2,715
800	1 10	2·15	0·40	2,800	6 51	8·82	1·75	4·5	840	18	2,845
900	1 24	2·44	0·50	2,900	7 12	9·21	1·85	5	925	19	2,975
1,000	1 38	2·73	0·55	3,000	7 33	9·60	1·95	5·5	1,010	20	3,100
1,100	1 52	3·02	0·60	3,100	7 55	10·0	2·00	6	1,095	21	3,220
1,200	2 6	3·32	0·65	3,200	8 17	10·41	2·10	6·5	1,175	22	3,335
1,300	2 21	3·63	0·75	3,300	8 39	10·83	2·15	7·	1,255	23	3,450
1,400	2 36	3·94	0·80	3,400	9 1	11·26	2·25	7·5	1,335	24	3,565
1,500	2 51	4·26	0·85	3,500	9 23	11·70	2·35	8	1,415	25	3,680
1,600	3 7	4·58	0·90	3,600	9 46	12·14	2·45	8·5	1,495	26	3,790
1,700	3 23	4·90	1·00	3,700	10 9	12·59	2·55	9	1,575	27	3,895
1,800	3 40	5·23	1·05	3,800	10 33	13·04	2·60	9·5	1,650	28	3,995
1,900	3 57	5·56	1·10	3,900	10 57	13·50	2·70	10	1,725		
2000	4 15	5·90	1·20	4,000	11 22	13·96	2·80				

Range Table for 12-pr. Rifled B.L. Gun of 8 Cwt.

Charge, 1 lb. 8 ozs. R.L.G. powder.

Projectile, segment shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze. E. Time.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze. E. Time.
yds.	° ′	secs	ins.	yds.	° ′	secs.	ins.
100	—	—	—	2,100	5 36	6·95	3·50
200	0 10	0·60	0·25	2,200	5 57	7·40	3·70
300	0 18	0·90	0·45	2,300	6 19	7·80	3·90
400	0 27	1·15	0·60	2,400	6 43	8·25	4·00
500	0 42	1·45	0·70	2,500	7 9	8·75	
600	0 58	1·75	0·85	2,600	7 36	9·25	
700	1 14	2·05	1·05	2,700	8 4	9·75	
800	1 32	2·40	1·20	2,800	8 33	10·25	
900	1 50	2·75	1·40	2,900			
1,000	2 8	3·05	1·55	3,000			
1,100	2 26	3·40	1·75	3,100			
1,200	2 44	3·70	1·90	3,200			
1,300	3 2	4·05	2·05	3,300			
1,400	3 20	4·40	2·20	3,400			
1,500	3 39	4·75	2·35	3,500			
1,600	3 58	5·10	2·55	3,600			
1,700	4 17	5·45	2·75	3,700			
1,800	4 36	5·80	2·95	3,800			
1,900	4 56	6·20	3·15	3,900			
2,000	5 16	6·60	3·30	4,000			

Range Table for 9-pr. Rifled B.L. Gun of 6 Cwt.

Charge, 1 lb. 2 ozs. R.L.G. powder.

Projectile, segment shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.
yds.	° ′	secs.	ins.	yds.	° ′	secs.	ins.
100	—	—	—	2,100	6 25	7·40	3·65
200	0 15	0·65	0·25	2,200	6 50	7·80	3·85
300	0 25	0·95	0·40	2,300	7 17	8·25	4·00
400	0 41	1·25	0·55	2,400	7 47	8·70	
500	0 59	1·60	0·75	2,500	8 19	9·15	
600	1 18	1·95	0·90	2,600	8 52	9·65	
700	1 37	2·25	1·05	2,700			
800	1 56	2·60	1·25	2,800			
900	2 15	2·95	1·40	2,900			
1,000	2 34	3·25	1·55	3,000			
1,100	2 53	3·60	1·75	3,100			
1,200	3 12	3·95	1·90	3,200			
1,300	3 31	4·30	2·10	3,300			
1,400	3 51	4·65	2·25	3,400			
1,500	4 12	5·05	2·45	3,500			
1,600	4 33	5·40	2·65	3,600			
1,700	4 54	5·75	2·80	3,700			
1,800	5 15	6·15	3·00	3,800			
1,900	5 38	6·55	3·20	3,900			
2,000	6 1	7·00	3·45	4,000			

Range Table for 16-pr. Rifled M.L. Gun of 12 Cwt.

Charge, 3 lbs. R.L.G. powder.

Projectile, common or Shrapnel shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.

Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Tenths of Fuze.
yds.	° ′	secs.		yds.	° ′	secs.	
100	0 0	0·25		2,000	4 15	5·90	
200	0 0	0·50	1	2,020	—	—	12
295	—	—	1·5	2,100	4 33	6·25	
300	0 7	0·76		2,165	—	—	13
390	—	—	2	2,200	4 51	6·60	
400	0 19	1·03		2,300	5 10	6·96	
485	—	—	2·5	2,305	—	—	14
				2,400	5 30	7·32	
500	0 31	1·30		2,445	—	—	15
575	—	—	3				
600	0 44	1·58		2,500	5 50	7·69	
665	—	—	3·5	2,580	—	—	16
700	0 57	1·86		2,600	6 10	8·06	
755	—	—	4	2,700	6 30	8·44	
800	1 10	2·15		2,715	—	—	17
840	—	—	4·5	2,800	6 51	8·82	
900	1 24	2·44		2,845	—	—	18
925	—	—	5	2,900	7 12	9·21	
				2,975	—	—	19
1,000	1 38	2·73					
1,010	—	—	5·5	3,000	7 33	9·60	
1,095	—	—	6	3,100	7 55	10·00	20
1,100	1 52	3·02		3,200	8 17	10·41	
1,175	—	—	6·5	3,220	—	—	21
1,200	2 6	3·32		3,300	8 39	10·83	
1,255	—	—	7	3,335	—	—	22
1,300	2 21	3·63		3,400	9 1	11·26	
1,335	—	—	7·5	3,450	—	—	23
1,400	2 36	3·94					
1,415	—	—	8	3,500	9 23	11·70	
1,495	—	—	8·5	3,565	—	—	24
				3,600	9 46	12·14	
1,500	2 51	4·26		3,680	—	—	25
1,575	—	—	9	3,700	10 9	12·59	
1,600	3 7	4·58		3,790	—	—	26
1,650	—	—	9·5	3,800	10 33	13·04	
1,700	3 23	4·90		3,895	—	—	27
1,725	—	—	10	3,900	10 57	13·50	
1,800	3 40	5·23		3,995	—	—	28
1,875	—	—	11				
1,900	3 57	5·56		4,000	11 22	13·96	

Range Table for 9-pr. Rifled M.L. Gun of 8 Cwt.

Charge, 1 lb. 12 ozs. R.L.G. powder.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								Fuze Scale.			
Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Range.	Tenths of Fuze.	Range.
yds.	° ′	secs.		yds.	° ′	secs.			yds.		yds.
100	0 0	0·25		2,100	5 2	6·50		0	0	11	1,835
200	0 6	0·50		2,200	5 24	6·90		1	200	12	1,965
300	0 14	0·80		2,300	5 47	7·30		1·5	300	13	2,095
400	0 26	1·05		2,400	6 10	7·70		2	400	14	2,225
500	0 39	1·35		2,500	6 34	8·10		2·5	500	15	2,355
600	0 52	1·70		2,600	6 59	8·50		3	600	16	2,475
700	1 5	1·95		2,700	7 25	8·90		3·5	700	17	2,595
800	1 18	2·25		2,800	7 52	9·30		4	800	18	2,705
900	1 31	2·55		2,900	8 20	9·80		4·5	880	19	2,810
1,000	1 44	2·85		3,000	8 48	10·30		5	960	20	2,910
1,100	1 57	3·20		3,100	9 18	10·80		5·5	1,035		
1,200	2 12	3·55		3,200	9 49	11·40		6	1,110		
1,300	2 28	3·85		3,300	10 21	12·00		6·5	1,185		
1,400	2 45	4·15		3,400	10 53	12·70		7	1,260		
1,500	3 2	4·45		3,500	11 27	13·45		7·5	1,335		
1,600	3 20	4·75		3,600				8	1,410		
1,700	3 38	5·10		3,700				8·5	1,485		
1,800	3 58	5·45		3,800				9	1,555		
1,900	4 18	5·80		3,900				9·5	1,625		
2,000	4 40	6·15		4,000				10	1,695		

Case shot, 300 yards = 1°.

Range Table for 7-pr. Rifled M.L. Steel Gun, 150 Lbs.

Charge, 4 ozs. F.G. powder.

Projectile, double shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								Fuze Scale.			
Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Range.	Tenths of Fuze.	Range.
yds.	° ′	secs.	in.	yds.					yds.		yds.
100	1 18	0·76	0·15	2,100				1	75	12	825
200	2 45	1·50	0·25	2,200				1·5	110	13	885
300	4 12	2·25	0·40	2,300				2	150	14	940
400	5 47	3·04	0·55	2,400				2·5	185	15	995
500	7 26	3·84	0·70	2,500				3	225	16	1,050
600	9 12	4·67	0·85	2,600				3·5	260	17	1,100
700	11 4	5·52	1·00	2,700				4	300	18	1,150
800	13 6	6·40	1·15	2,800				4·5	335	19	1,200
900	15 14	7·35	1·35	2,900				5	370	20	1,250
1,000	17 25	8·30	1·50	3,000				5·5	405	21	1,295
1,100	19 42	9·33	1·70	3,100				6	440	22	1,340
1,200	22 10	10·42	1·90	3,200				6·5	475	23	1,385
1,300	25 0	11·60	2·10	3,300				7	510	24	1,425
1,400	27 55	12·86	2·35	3,400				7·5	545	25	1,465
1,500	30 55	14·23	2·60	3,500				8	575	26	1,505
1,600	34 7	15·72	2·85	3,600				8·5	605	27	1,540
1,700	37 37	17·33	3·15	3,700				9	640	28	1,575
1,800				3,800				9·5	670	29	1,610
1,900				3,900				10	705	30	1,645
2,000				4,000				11	765	31	1,680
										32	1,710

Range Table for 7-pr. Rifled M.L. Steel Gun, 150 Lbs.

Charge, 6 ozs. F.G. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								Fuze Scale.			
Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Range.	Tenths of Fuze.	Range.
yds.	° ′	secs.	ins.	yds.					yds.		yds.
100	0 26	0·4	0·05	2,100				1	130	11	1,215
200	0 50	0·9	0·15	2,200				1·5	190	12	1,305
300	1 19	1·3	0·25	2,300				2	250	13	1,395
400	1 54	1·8	0·30	2,400				2·5	310	14	1,475
500	2 29	2·3	0·40	2,500				3	370	15	1,555
600	3 5	2·8	0·50	2,600				3·5	425	16	1,635
700	3 44	3·3	0·60	2,700				4	480	17	1,715
800	4 25	3·8	0·70	2,800				4·5	535	18	1,795
900	5 9	4·3	0·80	2,900				5	590	19	1,875
1,000	5 54	4·9	0·90	3,000				5·5	645	20	1,950
1,100	6 41	5·4	1·00	3,100				6	700	21	2,025
1,200	7 30	6·0	1·10	3,200				6·5	755		
1,300	8 21	6·6	1·20	3,300				7	810		
1,400	9·15	7·2	1·30	3,400				7·5	865		
1,500	10 14	7·9	1·45	3,500				8	915		
1,600	11 15	8·6	1·55	3,600				8·5	965		
1,700	12 21	9·3	1·70	3,700				9	1,015		
1,800	13 30	10·0	1·80	3,800				9·5	1,065		
1,900	14 44	10·7	1·95	3,900				10	1,120		
2,000	16 0	11·4	2·05	4,000							

Range Table for 7-pr. Rifled M.L. Bronze Gun, 200 Lbs.

Charge, 4 ozs. F.G. powder.
Projectile, double shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								Fuze Scale.			
Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Range.	Tenths of Fuze.	Range.
yds.	° ′	secs.	ins.	yds.					yds.		yds.
100	0 26	0·65	0·15	2,100				1	85	15	1,090
200	1 24	1·29	0·25	2,200				1·5	130	16	1,150
300	2 30	1·96	0·35	2,300				2	170	17	1,205
400	3 36	2·69	0·45	2,400				2·5	210	18	1,260
500	4 44	3·43	0·60	2,500				3	255	19	1,310
600	6 3	4·20	0·75	2,600				3·5	295	20	1,360
700	7 27	4·97	0·90	2,700				4	335	21	1,405
800	8 58	5·77	1·05	2,800				4·5	375	22	1,445
900	10 36	6·61	1·20	2,900				5	415	23	1,485
1,000	12 31	7·48	1·35	3,000				5·5	455	24	1,520
1,100	14 31	8·38	1·50	3,100				6	490	25	1,555
1,200	16 44	9·34	1·70	3,200				6·5	530	26	1,585
1,300	19 18	10·42	1·90	3,300				7	565	27	1,615
1,400	22 6	11·59	2·10	3,400				7·5	600	28	1,645
1,500	25 14	12·96	2·35	3,500				8	635	29	1,670
1,600	28 53	14·62	2·65	3,600				8·5	670	30	1,695
1,700	33 16	16·76	3·05	3,700				9	705	31	1,720
1,800	39 15	19·62	3·55	3,800				9·5	740	32	1,740
1,900				3,900				10	775	33	1,760
2,000				4,000				11	840	34	1,780
								12	905	35	1,795
								13	970	36	1,810
								14	1,030		

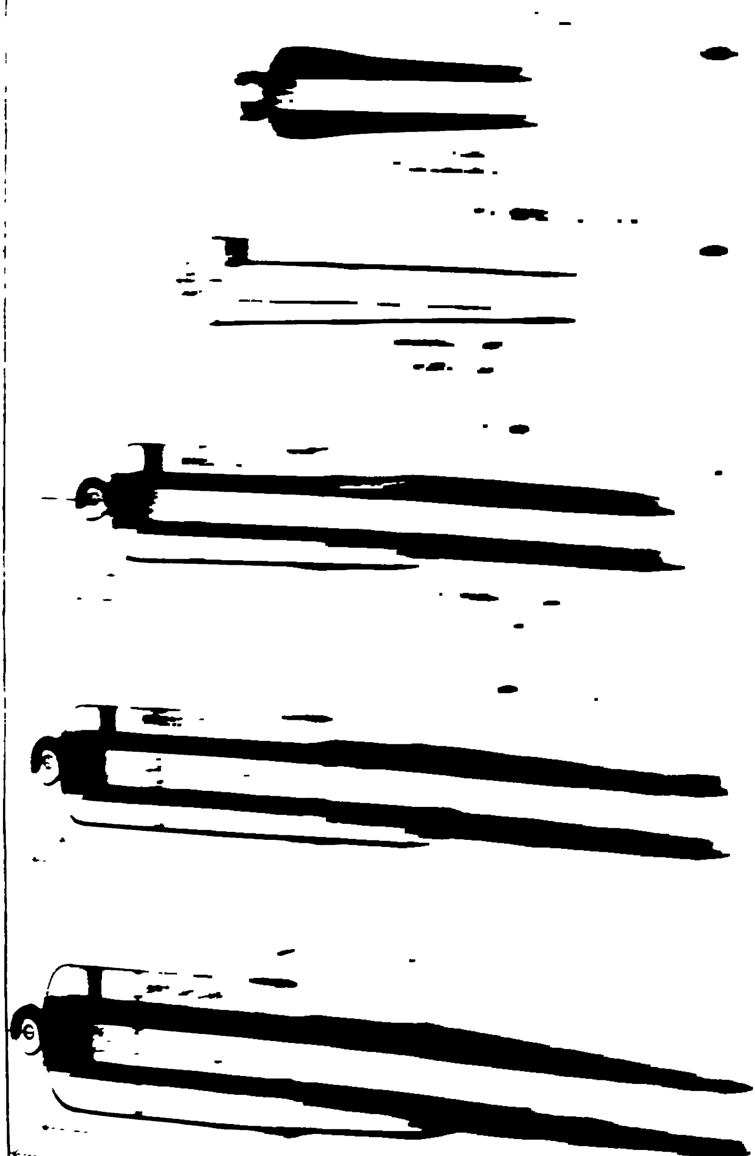
Range Table for 7-pr. Rifled M.L. Bronze Gun, 200 Lbs.

Charge, 8 ozs. F.G. powder.

Projectile, common shell.

Mean Elevation due to each 100 Yards of Range, by Interpolation.								Fuze Scale.			
Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Distance of Object.	Elevation.	Time of Flight.	Lengths of Fuze.	Tenths of Fuze.	Range.	Tenths of Fuze.	Range.
yds.	° ′	secs.	ins.	yds.	° ′	secs.	ins.		yds.		yds.
100	0 13	0·36	0·05	2,100	10 49	10·02	1·80	1	150	12	1,510
200	0 29	0·76	0·15	2,200	11 40	10·63	1·90	1·5	220	13	1,615
300	0 47	1·17	0·20	2,300	12 33	11·26	2·00	2	290	14	1,715
400	1 6	1·58	0·30	2,400	13 27	11·90	2·15	2·5	355	15	1,815
500	1 26	2·00	0·35	2,500	14 23	12·54	2·25	3	420	16	1,915
600	1 48	2·42	0·45	2,600	15 21	13·20	2·35	3·5	485	17	2,015
700	2 11	2·85	0·50	2,700	16 21	13·88	2·50	4	550	18	2,110
800	2 36	3·30	0·60	2,800	17 23	14·58	2·60	4·5	615	19	2,200
900	3 3	3·76	0·65	2,900	18 27	15·30	2·75	5	680	20	2,290
1,000	3 31	4·23	0·75	3,000	19 32	16·04	2·85	5·5	745	21	2,380
1,100	4 0	4·70	0·85	3,100	20 39	16·80	3·00	6	810	22	2,470
1,200	4 31	5·18	0·95	3,200				6·5	875	23	2,555
1,300	5 5	5·67	1·00	3,300				7	935	24	2,640
1,400	5 41	6·17	1·10	3,400				7·5	995	25	2,720
1,500	6 19	6·68	1·20	3,500				8	1,055	26	2,800
1,600	6 59	7·20	1·30	3,600				8·5	1,115	27	2,875
1,700	7 41	7·74	1·40	3,700				9	1,175	28	2,950
1,800	8 25	8·30	1·50	3,800				9·5	1,230	29	3,025
1,900	9 11	8·86	1·60	3,900				10	1,285	30	3,100
2,000	9 59	9·43	1·70	4,000				11	1,400		

INDEX.



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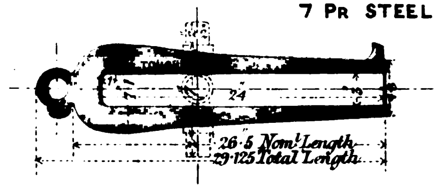
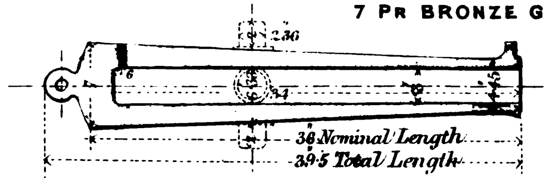
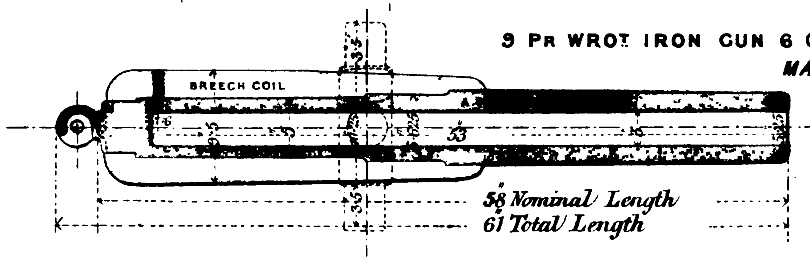


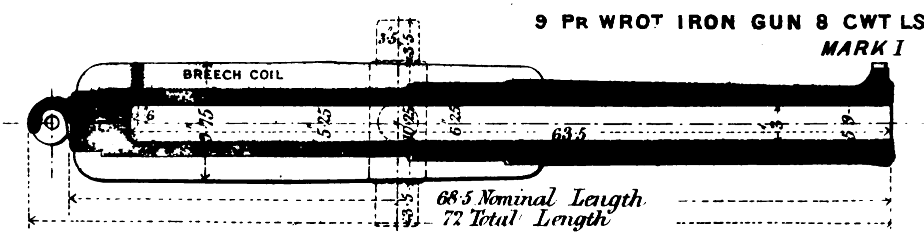
7 PR BRONZE GUN 224 LBS
MARK III



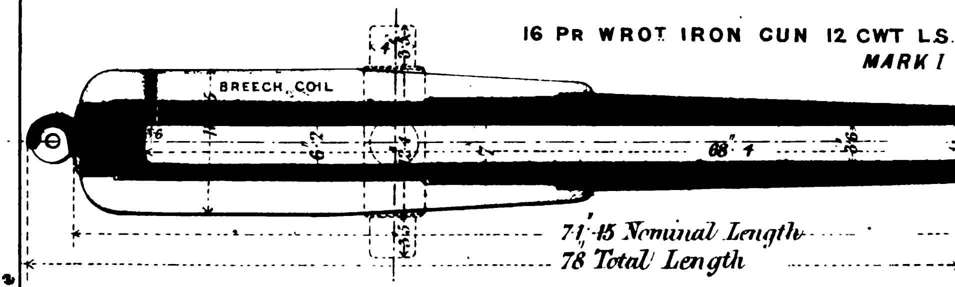
9 PR WROT IRON GUN 6 CWT. S.S.
MARK I



9 PR WROT IRON GUN 8 CWT L.S.
MARK I



16 PR WROT IRON GUN 12 CWT L.S.
MARK I



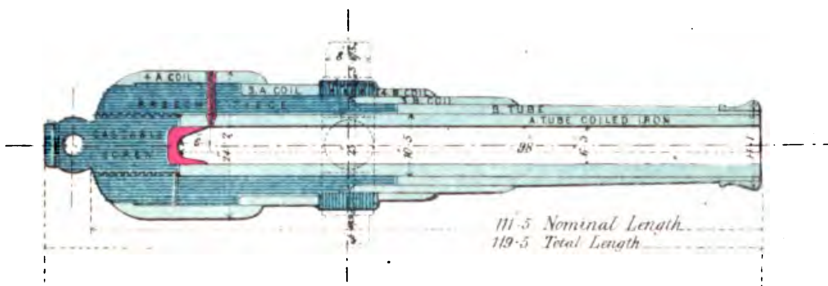
H. W. Jones R. G. F. Del.

Vincent Brooks Day & Son

WROT IRON RIFLED MUZZLE LOADING 64 PR. GUNS OF 64 CWT.

Scale. ⅜ Inch = 1 Foot.

MARK I.



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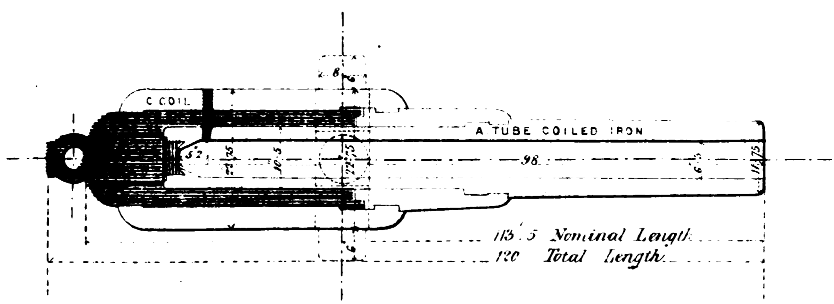
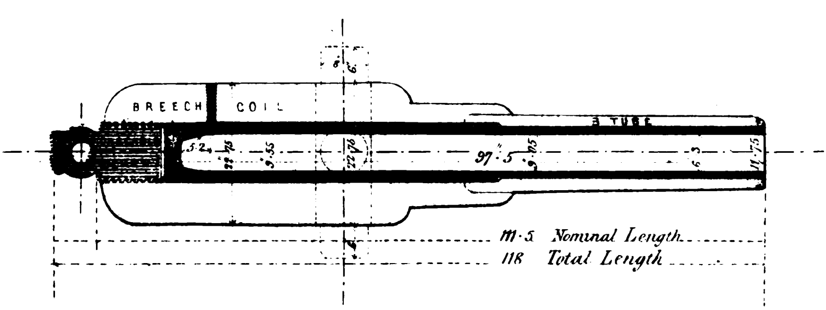


MARK III.



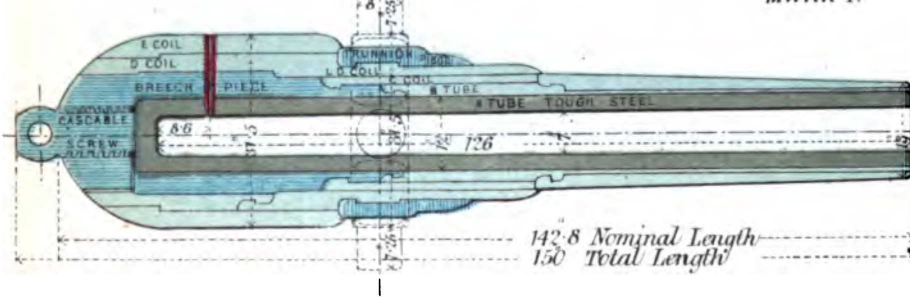
H W Jones R.G.F. Del. Vincent Brooks Da

PL. III.

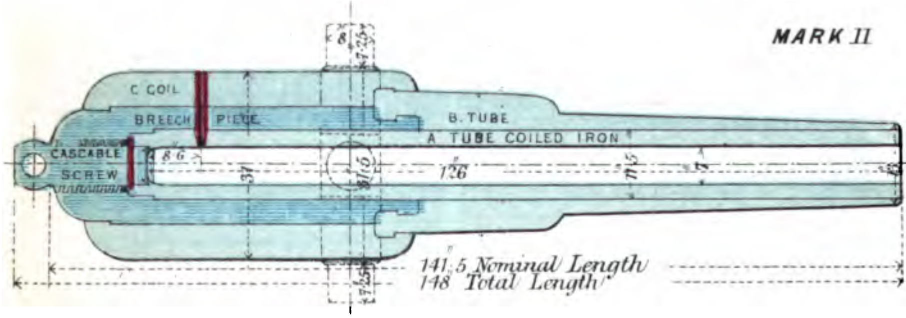
WROT IRON RIFLED MUZZLE LOADING 7 INCH GUNS OF 7 TONS.

Scale, 3/8 Inch - 1 Foot

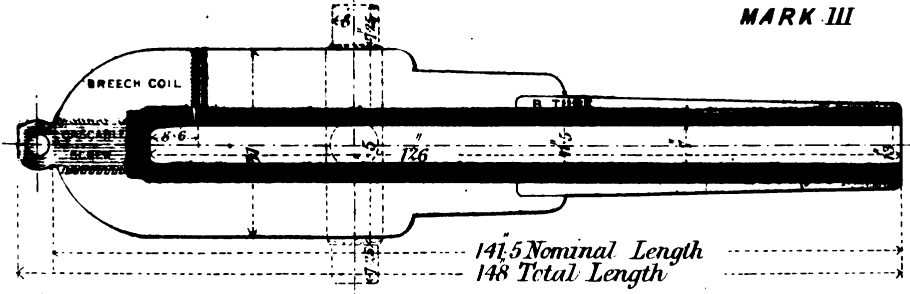
MARK I.



MARK II



MARK III

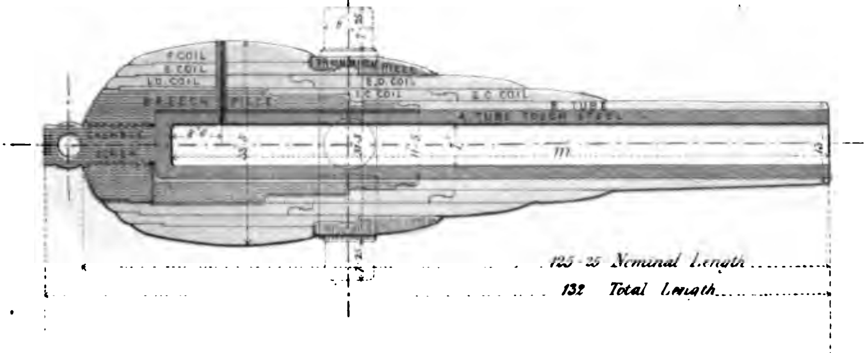


Vincent Brooks, Day & S.

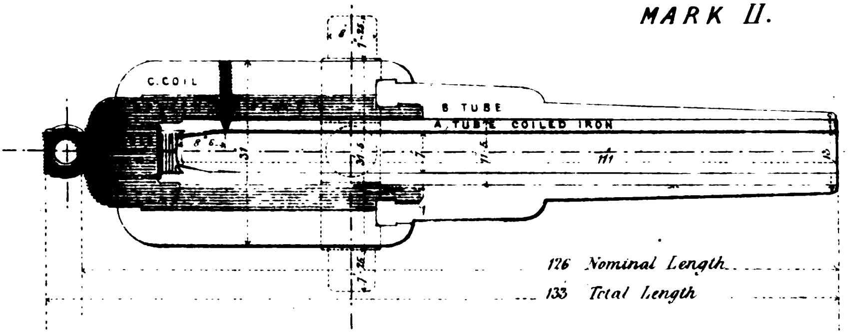
WROT IRON RIFLED MUZZLE LOADING 7 INCH GUNS OF 6½ TONS.

Scale – ⅜ Inch – 1 Foot.

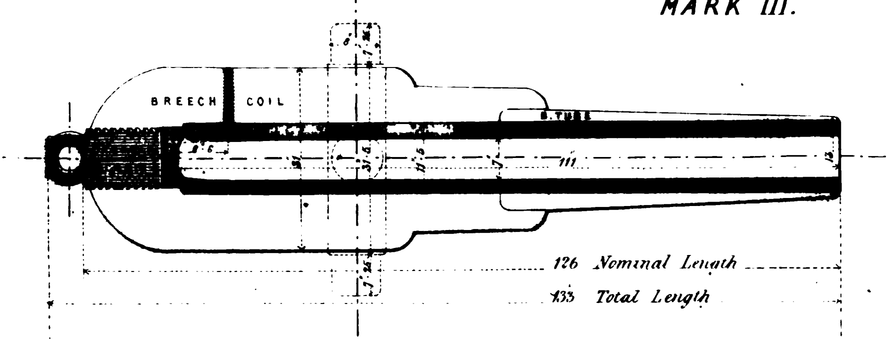
MARK I.



MARK II.



MARK III.



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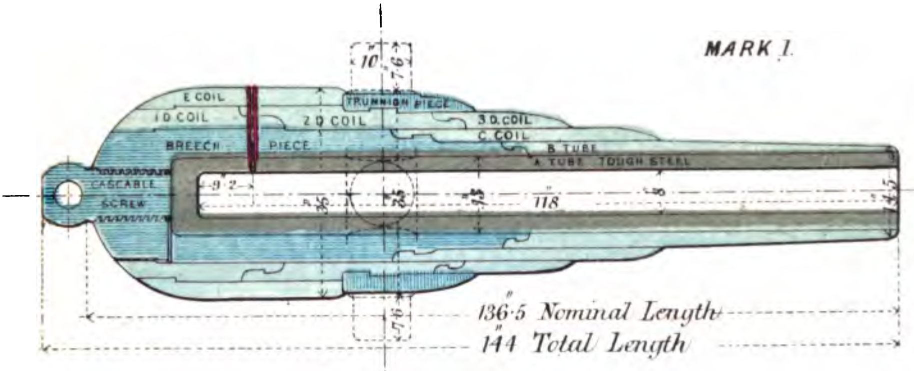
PL. V.

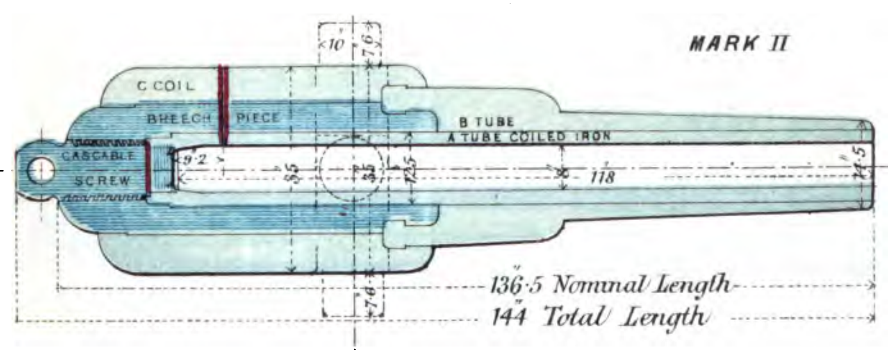
WROT. IRON RIFLED MUZZLE LOADING 8 INCH GUNS OF 9 TONS.

Scale 3/8 Inch 1 Foot

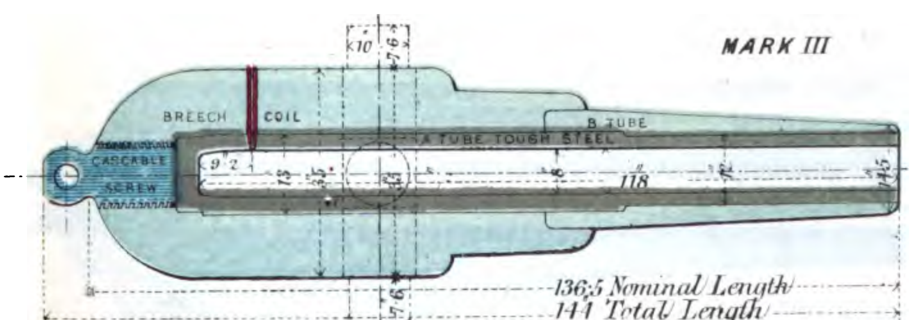
MARK I.



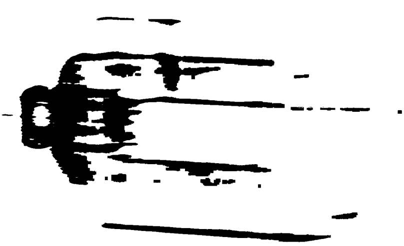
MARK II



MARK III

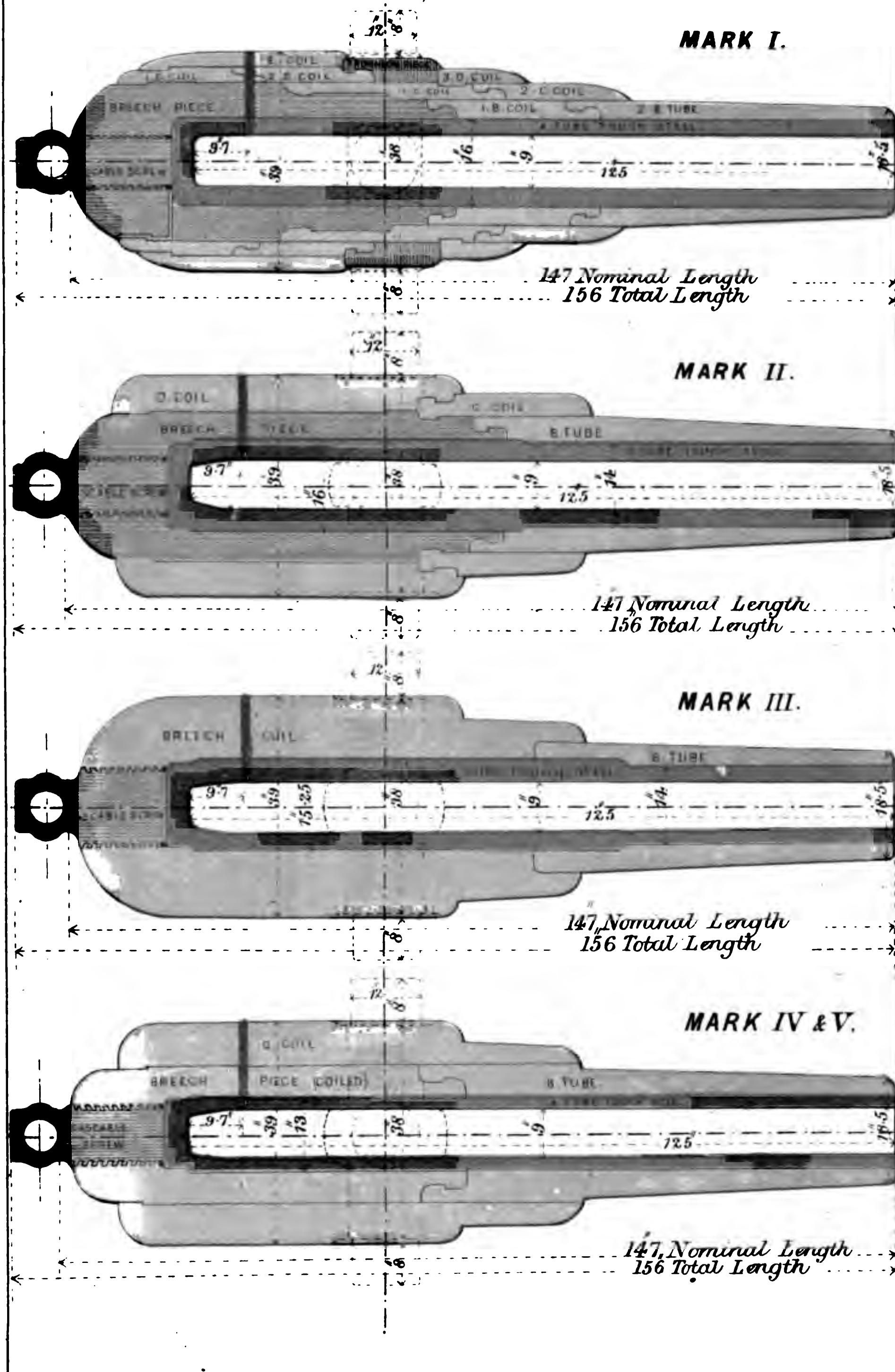


WRO^T IRON RIFLED MUZZLE LOADING



WROT IRON RIFLED MUZZLE LOADING 9 INCH GUNS OF 12 TONS.

Scale 3/8 Inch = 1 Foot.



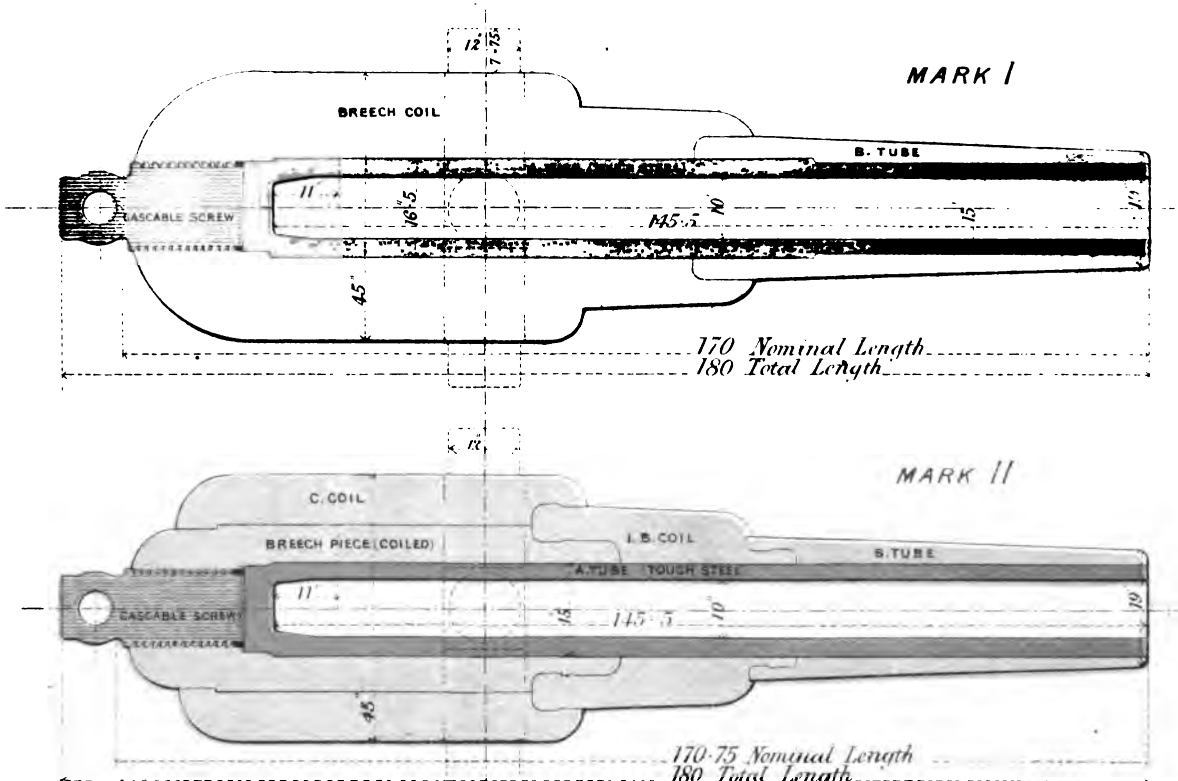
H W Jones R.G.F. Del.

Vinc. & Brooks, Day

WROUGHT IRON RIFLED MUZZLE LOADING 10 INCH GUN 18 TONS.

Scale 3/8 inch - 1 Foot.

Note. These Guns when intended for Broadside use in the Navy and for Land Service are vented upon the right-hand side at an angle of 45° with the vertical axis of gun. But when employed in double gun turrets are vented right and left i.e. upon the outsides of their respective positions.



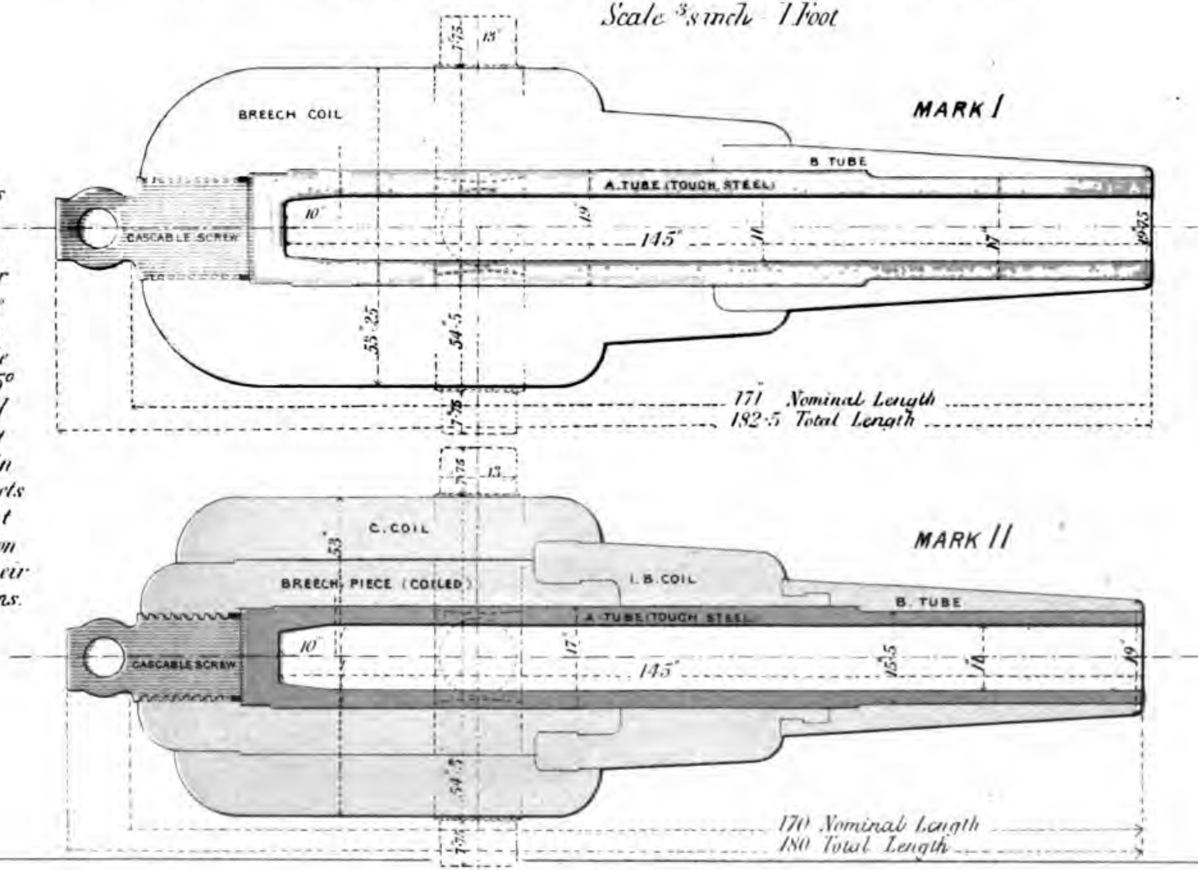
...es R.G.F. Del

WROUGHT IRON RIFLED MUZZLE LOADING 11 INCH GUN 25 TONS.

PL. VIII.

Scale 3/8 inch = 1 Foot

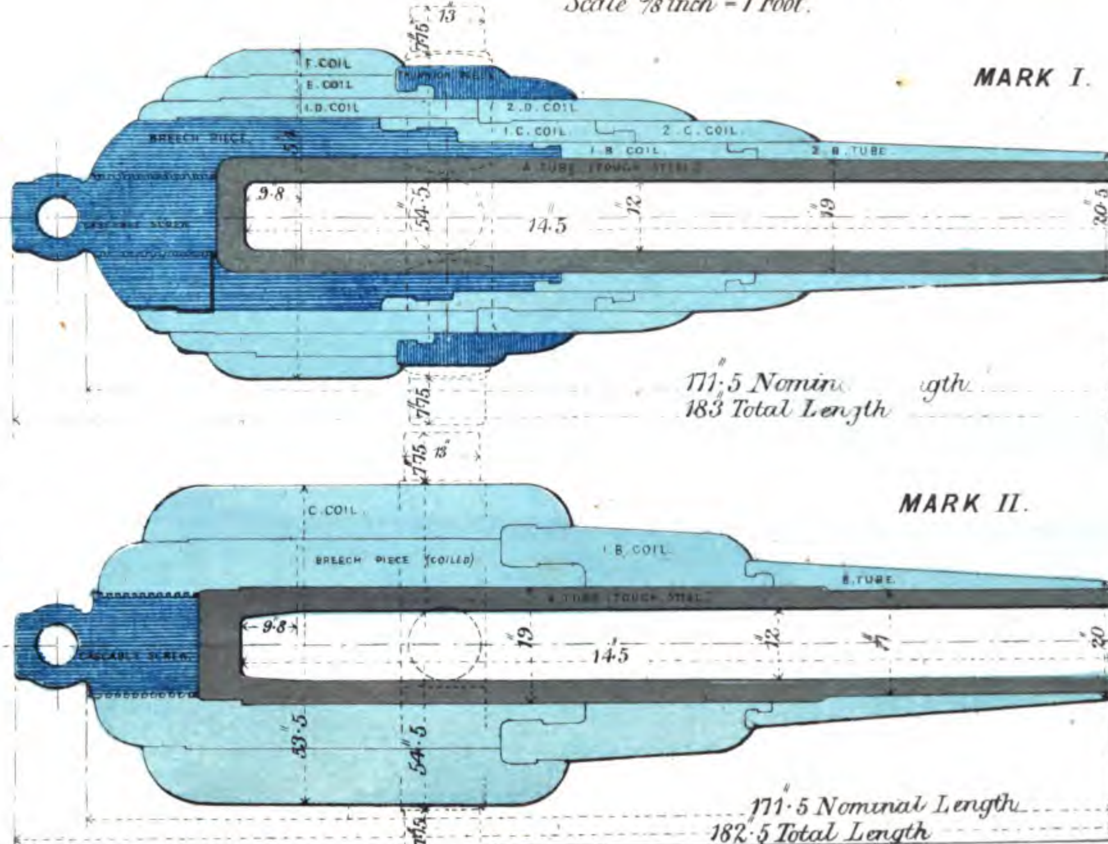
Note. These Guns when intended for Broadside use in the Navy and for Land Service are vented upon the right-hand side at an angle of 45° with the vertical axis of gun. But when employed in double gun turrets are vented right and left i.e. upon the outsides of their respective positions.



Pl. IX.

WROUGHT IRON RIFLED MUZZLE-LOADING 12 INCH GUN 25 TONS.

Scale 3/8 inch = 1 Foot.



Note. These Guns when intended for Broadside use in the Navy and for Land Service are vented upon the right-hand side at an angle of 45° with the vertical axis of gun. But when employed in double gun turrets are vented right and left i.e. upon the outsides of their respective positions.

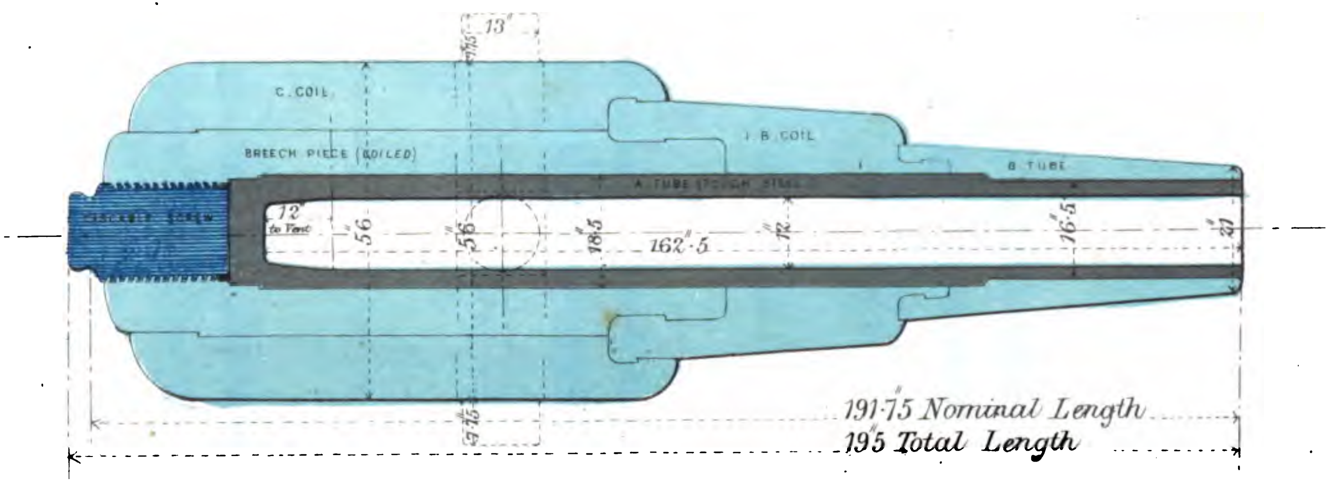
...es R.G.F. Del

Vincent, Brooks Day & Son Lith

Pl. X.

WROUGHT IRON RIFLED MUZZLE-LOADING 12 INCH GUN 35 TONS.

Scale 3/8 inch – 1 Foot.



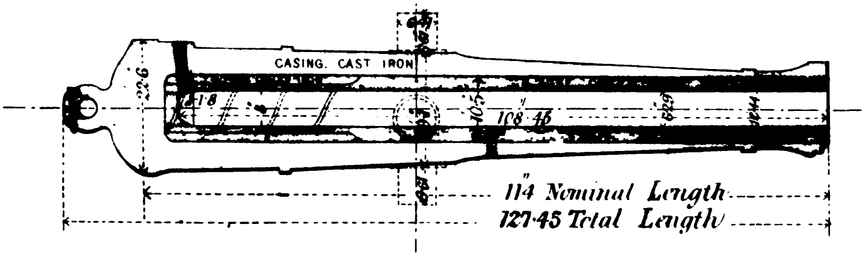
...nes R.G.F. Del

Vincent Brooks, Day & Son, Lith.

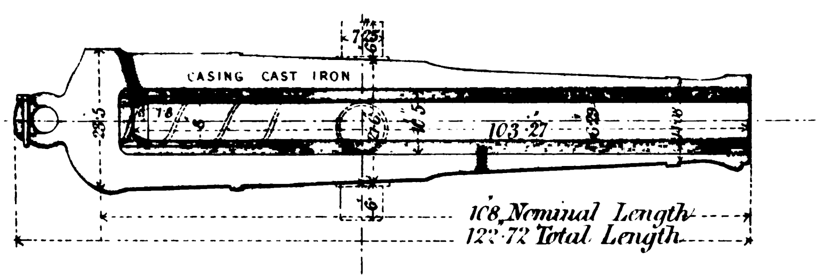
CONVERTED RIFLED M. L. GUNS.

Scale ⅜ Inch = 1 Foot

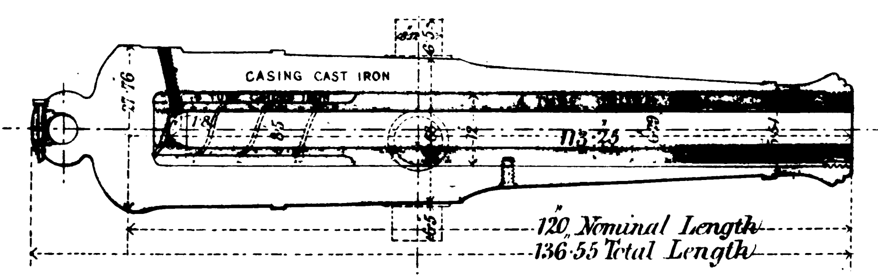
64 Pr. 58 CWT: FROM 32 Pr. 58 CWT:



64 Pr. 71 CWT FROM 8 In: 65 CWT:



80 Pr. 5 TONS FROM 68 Pr. 95 CWT:



H. W. Jones R.G.F. Del. Vincent Brooks Day & Son